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Hehir's Sanitary Science Series.

A
CATECHISM
OF
HYGIENE AND SANITARY SCIENCE.

BY

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PART I.—WATER.

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PREFACE.

MANY years ago, when reading for various examinations in Hygiene and Sanitary Science, and especially when preparing other candidates for such examinations, the Author felt the necessity of some Series such as he now presents to students. It was then that he conceived the plan of the present work, athough its scope has vastly exceeded the limits originally intended, and no pains have been spared to make it acceptable to students.

When the idea was seriously taken in hand, it was not conceived possible for it to attain its present magnitude, but it grew page by page, until it now speaks for itself.

In a work which contains so much matter of fact, it is almost inevitable for a first edition to contain a certain number of errors; these, however, will most frequently be found to be of a clerical or typographical nature, and it is hoped that should the Series pass through a second edition all such errors will be eliminated; and in this connection, it is unnecessary here to allude to the many difficulties which an Author in an up-country station in India has to contend with in regard to passing a work of this kind through a non-medical press situated in a Presidency town. This Series is the product of fifteen years' work, and during a large part of this time the Author has been directly engaged either as a teacher of Hygiene or as a Sanitary Officer.

The earlier stage of the collection of the matter was not connected with the out-put of this Series, as the notes culled from various sources were for the writer's personal use. In this way, in making such notes and abstracts from various works, he omitted in some instances to record the names of Authors quoted. For this omission he apologizes

The appended list of books will indicate that practically every important work on the subject of water and water-supplies has been consulted in the preparation of this *Part I*—WATER—of this Series.

The Author cannot express sufficiently the degree of his obligations to the various writers whose works he has made use of. He desires especially to express his indebtedness to the following works:—

PARKES' *Practical Hygiene, 7th Ed., edited by Prof.* F. DE CHAUMONT.

GORDON BUCK'S *Hygiene and Public Health.*

STEVENSON AND MURPHY'S *Treatise on Public Health, Vols. I and II.*

LOUIS PARKES' *Hygiene and Public Health, 3rd Ed.*

WILSON'S *Handbook of Hygiene, 6th Ed.*

MACDONALD'S *Microscopical Examinations of Drinking Water and of Air.*

WANKLYN'S *Water Analysis.*

FRANKLAND'S *do. do.*

HUSBAND'S *Medical Police.*

WILLOUGHBY'S *Hygiene and its Principles.*

ALLEN'S *Aids to Public Health, Part I.*

NEWSHOLME'S *Hygiene.*

BLYTH'S *Dictionary of Hygiene and Public Health*; the same Author's *Hygiene and Public Health.*

BEARDMORE'S *Hydrology.*

JACKSON'S *Hydraulic Manual.*

PEPPER'S *System of Medicine.*

AITKIN'S *Science and Practice of Medicine.*

Various Volumes of the Sanitary Record.

LEUCKART'S *Parasites of Man.*

SPON'S *Dictionary of Engineering.*

RANKINE'S *Civil Engineering.*

SHIRLEY MURPHY'S *Our Homes and How to Take Care of Them.*

BALDWIN LATHAM'S *Sanitary Engineering.*

DASCHASENEL'S *Natural Philosophy.*

FANNING'S *Treatise on Hydraulic and Water-Supply Engineering.*

A more complete Bibliography is published at the end of this volume.

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P. H.

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A
CATECHISM OF HYGIENE
AND
SANITARY SCIENCE.

Part I.—WATER.

CHAPTER I.

1.—*What is the composition of water?*

Water is a compound of two gases, *oxygen* and *hydrogen*, in the proportion of one volume of the former to two of the latter. This is shown by splitting up water into its elements, which may be effected by means of the two poles of an electrical apparatus; or by bringing the two gases together in proper quantities, and passing an electric spark through them: water is then formed, the two gases combining to form it—its chemical formula being H_2O.

2.—*What are the physical characters of water?*

Pure water is a tasteless, odourless, and transparent fluid, and with the exception of a faintly bluish tinge when viewed through a depth of two or three feet, it is colourless. It boils at a temperature of 212° F. (under the ordinary barometric pressure of 760 millimetres of mercury), and freezes at 32° F. It contracts regularly until it reaches a temperature of 4° C., but below this temperature it begins to expand and continues to do so until it freezes. In this physical property we see that it is affected in a manner dissimilar to all other compounds, and upon this physical peculiarity depends the fact that in certain parts of the world, at particular periods of the year, the water of certain seas and rivers does not congeal, *en masse.* It forms a convenient standard with which to compare the specific gravity of liquids, water being reckoned as unity.

3.—*What are the special physical properties of water as regards its weight, pressure, and motion?*

If we consider those qualities of water that have reference to its weight, its pressure, and its motion, we shall observe, especially, that the volume of the liquid is composed of an immense number of minute particles; that each particle has weight individually; that each particle can receive and transmit the effect of weight, in the form of pressure, in all directions; and that the particles move past and upon each other with very slight resistance. Each molecule has its individual weight, and is subject, independently, to the force of gravity. Each molecule presses in any direction from which a sufficient resistance is opposed, with a pressure due to the combined natural pressures of all molecules acting upon it in that direction, and also with the pressure transmitted through them from any exterior force. In treatises on hydrostatics, propositions relating to pressures of fluids are commonly stated in some form similar to the following: "When a fluid is pressed by its own weight, or by any other force at any point it presses equally in all directions."

4.—*What should be the characteristics of a good and wholesome water?*

(1) It should be limpid, odourless, preferably colourless, and transparent, cool, well aerated, bright, soft, and free from taste and suspended matter of any sort. It should also be fresh, and its temperature not higher than 15° C.

(2) It should contain no animal or vegetable matter, especially if such matter is decomposing.

(3) It should not contain an undue amount of solid constituents, especially when such constituents are salts of lime or magnesium. The amount of solids should not exceed *eight grains per gallon,* one grain of which should be alone dissipated by heat. In chalk waters the solids should not be more than *fourteen grains* per gallon. Wanklyn, however, holds that unless a water contains more than forty grains of solids per gallon, no exception need be taken to the solids as such.

(4) It should be practically free from nitrogenous organic matter, the "albuminoid ammonia" being less than 0 05 parts per million, and a water should be regarded with suspicion, which, along with a considerable quantity of free ammonia, yields ·05 part of albuminoid ammonia per million.

(5) After being kept some time in either an open or closed vessel it should not acquire any disagreeable odour.

(6) It should be destitute of bacteria, infusoria, white algæ, and other living organisms.

(7) The air that it *ought* to hold in solution should contain a larger proportion of oxygen than ordinary air.

(8) A litre of the water should not contain more than—

Mineral salts	0·5	gramme.
Chlorine	0·008	„
Sulphuric anhydride	0·06	„
Nitric anhydride	0·002	„
Alkaline salts	0·2	„
Silica	0·03	„
Iron	0·003	„
Sulphuretted hydrogen	none at all.	

5.—*What are the characteristics of well-aerated water?*

It is lustrous, sparkling, bright, and highly palatable.

6.—*Where are such waters generally found?*

In springs and in wells of moderate depth, sunk in chalk strata. In these the high pressure and comparatively low temperature help to increase the quantity of carbonic acid gas held in solution.

7.—*Classify waters as regards their wholesomeness and palatability?*

The comparative merits of the various waters in respect of wholesomeness, palatability, and general fitness for drinking and cooking purposes, are given in the following table:—*

Wholesome	1. Spring water	Very palatable.
	2. Deep well water	
	3. Upland surface water	Moderately palatable.
Suspicious	4. Stored river water	
	5. Surface water from cultivated land	Palatable.
Dangerous	6. River water to which sewage gains access	
	7. Smaller well water	

8.—*How may we classify waters for practical purposes?*

Into—

(1) Pure and wholesome water.

(2) Usable water.

(3) Suspicious water.

(4) Impure water.

---

* Vide *Sixth Report of the Rivers Pollution Commissioners.*

9.—*What are the chief physical characteristics of waters according to the classification given in Question 8?*

The following table indicates the chief physical characteristics of waters of the classification given in Question 8:—

Character or constituent.	Pure and wholesome water.	Usable water.	Suspicious water.	Impure water.	Remarks.
Clearness, lustre, and aëration.	Transparent, sparkling, and well aërated.	Transparent, sparkling, and well aerated.	Turbid ...	Subsoil and not easily purified by coarse filtration.	Turbidity due to very fine aërial matter is sometimes associated with pure waters; thus, minutely divided calcium sulphate will not subside in distilled water.
Suspended matter.	Detectable by the eye.	Absent or easily separable by coarse filtration or subsidence.	Considerable	Large ...	
Colour ...	Colourless ...	Colourless or slightly greenish.	Yellowish ...	Distinctly yellow or any marked colour.	When the impurity is mostly vegetable, the colour may be very marked in good, or at least usable, water.
Taste ...	Palatable ...	Any marked taste.	Any marked taste.	...	...
Smell ...	None ..	None ...	...	...	...

10.—*What are potable waters?*

Waters which are fit for habitual use for drinking purposes, either in the natural condition, or after having been subjected to such simple processes of purification as subsidence and filtration.

11.—*What is the significance of the term "pure" as applied to water?*

The term "pure" as applied to water is used in two distinct senses,—one in which the water is *chemically* pure, and in which it contains nothing but water; the other in which it is *hygienically* pure, and in which, although certain foreign constituents are dissolved or contained in the water, they are not in sufficient quantities to produce any deleterious effect on the human economy. The extraneous constituents of a hygienically pure water are not only harmless, but are actually beneficial. A chemically pure water is not suitable for constant use as a beverage.

Absolute chemical purity, in the sense of freedom from all foreign substances, is neither possible nor desirable. The surface-waters of uninhabited granitic and gneissic regions are often very free from foreign matters; but even they, in their passage through the air and over the ground, dissolve gaseous and solid substances. Most of the mineral substances which make up the earth's crust are either more or less soluble in water, or are decomposed by water with the production of soluble compounds. The more common mineral substances thus occurring in natural water are the chlorides, sulphates and carbonates of sodium, potassium, magnesium, and calcium, together with silica, alumina, and iron, in some form of combination. Organic matter of animal or vegetable origin also occurs in most waters; it is various in character, and of very diverse sanitary importance.

12.—*What are the purest natural waters?*

Rain and snow water collected on a clean and prepared surface situated remote from habitations; it contains but little solid matter and traces of NH_3, nitrites and nitrates, some O, N, and CO_2 in solution; lake water of mountainous regions as Lake Katrine near Glasgow, and the lakes of Westmoreland; similar water in low mountainous regions.

13.—*Is pure water to be found in nature?*

The nearest approach to purity in nature is rain water falling in rural districts and collected in clean vessels. Chemically pure water is unknown in nature, and can only with difficulty be prepared. Distilled water is the purest water obtainable, but even this is free from all foreign constitutents.

14.—*How may we obtain perfectly pure water?*

It can only be artificially prepared by very careful distillation in the chemist's laboratory—the clearest ice, the most transparent rain water, the whitest snow, all contain air and certain mineral and organic matters although in small quantities only.

15.—*What may be said with regard to the revolution of water from the time it leaves the ocean till it returns?*

That all the water of the earth has performed this cycle over and over again, and as regards its relation to the animal kingdom, it may be stated that there is no reason to doubt that every drop of water on the surface of the earth has, at one time or other, passed through the intestinal canal of some animal, just as every cubic inch of the atmosphere has been breathed over and over again.

16.—*What may be said in regard to the advisability of providing a community with a permanent supply of wholesome water?*

It ought to be a recognised principle of sanitation, that wherever a permanent supply of good water is available, it should be provided for the people. No reasonable amount of labour or expense should be spared to get water from a pure source. It is only by so doing that we can entirely remove from the lower classes the power of polluting water supplies. Locked up in water pipes, the water cannot be got at. It is thus that we shall help to lessen, if we cannot stamp out, the ravages of cholera and other diseases communicable by water, such as enteric fever, etc. We must remember that a deficiency of pure water in a community brings about accumulation of filth in all its forms, with all its evils.

17.—*What are the uses of water?*

The uses of water in civilised communities are many:—

(1) It is an essential part of our daily food. It serves to effect the excretion of effete products from the body, and helps to lubricate and build up the tissues. By its evaporation from the surface of the body it cools the system. It is really more important than food itself: for without it, food could not be used. It is necessary to aid in dissolving, digesting and assimilating the food, which, through these processes, is so altered as to be rendered fit for circulating through the body. For these reasons alone the vital importance of water in the animal economy is evident. It forms about 66 per cent. of the whole body, or in plainer terms, a man weighing 154 lbs. has in his body about 12 gallons of water, that is, enough to drown him if suitably arranged. It forms one of the chief constituents of the juices and tissues of the human body.

(2) It is the closest approach yet discovered to the long-sought-for universal solvent (of the alchemists).

(3) It is necessary for personal cleanliness. This is perhaps the best place to remark upon the necessity of public bathing places. This cannot be too strenuously insisted upon, and the water in these should, if possible, be kept clean by constant removal and periodical cleansing of the baths.

(4) As a household requirement, it is used for cooking, for cleaning utensils, floors, etc.

(5) It is necessary for washing our linen.

(6) For public purposes, it is used for watering streets and extinguishing fires. Among the greater advantages of an ample supply of water may be enumerated the cleansing of drains effected by copious daily flushing. The semi-fluid putrid material found sluggishly flowing in sewers is no small factor in the production of disease amongst communities. The great object of sewers is to remove, with as little delay as possible, the foul refuse of our bodies and houses from our surroundings, and this can only be effected by regular periodical flushing. After the introduction of an adequate public water-supply to towns, were it rendered compulsory, that every house tenant, stable, etc., should be furnished with water from this source, irrespective of private or public wells, it would go far to improve the sanitary condition of the towns, to promote health and lessen disease and mortality.

(7) It is required for drinking purposes for horses and other domestic animals, as well as for washing these animals and cleaning carriages.

(8) It is also required in manufacturing processes. But its uses do not end here. Taking advantage of its incompressibility in the liquid form, and its elasticity in the gaseous state, by it we are enabled to carry out our most powerful mechanical processes. Indirectly it purifies the soil and air. The rain clears the air by washing it, and finally the rain washes the soil.

Water has also its therapeutical uses. In cases of fever, especially those fevers associated with high temperature, it affords a direct means of getting rid of the excessive heat of the body. We need scarcely be reminded that cold water is one of the best available means of reducing local inflammations. It would be out of place to do more than merely mention the part played by the waters of the different Spas of Europe. Its various applicabilities in these institutions is due, however, in part to the extraneous agents the water contains.

To effect all these purposes, a liberal supply is required, and a really hygienic state of a house, its surroundings and inmates cannot exist without such a supply. A community will, as a rule, be found unhealthy in proportion as its supply of water is scanty. Such scantiness means imperfect cleansing, together with, in a great many cases, impurity in quality. Water is a universal beverage, and when pure, it is perhaps the only one necessary for persons in health.

18.—*What is the relation of water to the human body, and what part does it play as a food?*

It is both a food and a solvent. Our tissues and organs contain much water, part of which is free and uncombined, the other part is in close union with them; one part soaks and imbues the tissues and organs, the other forms part of their structure. An adult man when in moderate labour requires about 46 ounces of so-called dry food to keep him in health. About one-half of this consists of water, so that only about 23 ounces is really solid, dry, food. An average adult loses from the skin, kidney, and lungs about 80 ounces of water daily. He requires, therefore, a similar quantity to make up for this loss. Some foods contain a large amount of water. Beef or mutton contains 75 per cent.; in other words, 1 lb. of either of these consists of 12 ounces of water and 4 ounces of dry solid meat. Vegetables contain from 85 to 98 per cent. of water. Such vegetables as turnips and cucumbers are almost all water; fresh fruit is much the same in this respect.

19.—*What are the other uses of water in the functions of the human economy?*

Water serves many other purposes in the human economy: (1) It keeps the blood in a fluid state, in which form alone it could carry out its function as a nourishing medium to the organs and tissues of the body. If the blood contains less than a certain amount of water, it becomes so thick that it cannot pass through the capillaries as occurs, for instance, in cholera. Water acts as a general solvent, by means of which property it serves to elaborate the blood and convey nutriment to all parts of the body. It also serves to build up new tissues and repair old. So long as water is taken, the absence of all other food can be borne for a comparatively long time. When deprived of food and water, it is thirst we feel most and soonest. This thirst is felt in the mouth and throat, but this is merely a local sensation expressing a demand on the part of the economy for additional fluid.

20.—*What is the proportion of water to solids in the body?*

Two-thirds of the entire weight of the body consists of water, which enters into the constitution of every tissue and structure of the organism.

21.—*What are the purposes for which water is supplied by public water works?*

For drinking, cooking, and ablution of persons, clothes, utensils, and houses; for cleansing of drains, sewers, closets and streets; for drinking and washing of animals, washing of carriages and stables; for trades and manufactories; for baths and fountains, for extinguishing fires; production of steam, manufacture of ice, etc.

22.—*What is the importance of water in the animal economy?*

Water is one of the prime necessities of life. Deprived of it for some days, the functions of the living econony come to an end.

This holds good with all animal and almost all vegetable life. A few of the lowest *fungi*—especially the germs of some diseases, such as small-pox and anthrax, retain in the dessicated state, a latent vitality; but in this dried condition their power of multiplication is removed. They cannot be resuscitated in the absence of moisture in some form or other.

Water is being constantly lost to the body by the skin, the kidneys, and by the lungs, and to replace this loss we require a certain amount of liquid either as water or as a beverage. (*Vide* Ans. 18.)

23.—*What is the relation of drinking water to the gases it contains or may contain?*

Water is an active absorbent of many gases, and from this property both innocuous and injurious gases may gain access to it.

Rain water, and all other natural waters, are more or less charged with the gases of the air. These are chiefly oxygen, nitrogen, and carbonic acid gas. Twenty-five gallons of water will contain about five pints of these gases. In ordinary air the proportion of *oxygen* to nitrogen is about 1 to 4; but as oxygen is more soluble than nitrogen in water, water contains more of it. The carbonic acid gas of the air is also dissolved in rain water, but in comparatively small amounts. Twenty-five gallons of lake or tank water seldom contain more than a quarter or half a pint of dissolved *carbonic acid gas*. This gas is very soluble in water, but as only four parts of it are contained in 10,000 parts of air, rain water also contains but a small amount of it. But ordinary river and well waters contain considerable quantities of carbonic acid gas. This is accounted for by the fact that in the decomposition and oxidation of the organic matter which gains access to rivers and wells, carbonic acid is generated and dissolved. Water falling on the ground, finds its way to the animal and vegetable matter in the soil. The oxygen already dissolved in the water, oxidises the organic matter, and carbonic acid is given off in the process of decomposition. The water, deprived of its oxygen, absorbs a fresh supply from the air, and the formation of additional quantities of carbonic acid gas is repeated; so that the water becomes more and more saturated with it. Such is the main source of carbonic acid in various waters. It is the existence of this carbonic acid gas that gives good water the pleasant briskness, freshness and sharpness to the palate.

There is yet another source of carbonic gas in water that traverses the soil, *viz.*, the air of the soil itself. The air in the surface soil contains a considerable amount of carbonic acid gas (about 200 times as much as ordinary air, the proportion increasing as the depth increases). This carbonic acid gas has likewise been formed by organic decomposition. The water in its passage through the soil carries much of this carbonic acid with it, and this carbonic acid dissolves out any minerals met with that are soluble in a carbonic acid water.

24.—*How much oxygen, nitrogen, and carbonic acid gas can a litre of water dissolve?*

A litre of water can dissolve 25 c.c. of oxygen, 46 c.c. of nitrogen, and 10 c.c. of carbonic acid, at the ordinary temperature and pressure of the atmosphere.

25.—*Are these gases contained in water as a rule?*

These gases are usually present in natural waters, but the portions are very variable, being largely dependent upon the source of the water, the degree of pollution and of exposure to air, and also upon vegetable growth. Chalk and limestone waters contain excess of carbonic acid gas. The gases in a pure water often contain 30 per cent. of their volume of oxygen.

26.—*How may they be extracted for the purpose of quantitative analysis?*

By means of a Sprengle pump,* or by boiling the water for an hour, and collecting the gases over a mercurial trough. Potash will then absorb the carbonic acid, and potassic pyrogallate or sodic hyposulphite will remove the oxygen, leaving a residue of nitrogen alone.†

27.—*What are the gases most usually present in water?*

Oxygen, nitrogen, carbon dioxide, hydrogen sulphide, and marsh gas. If the three former co-exist, as is generally the case, the oxygen is usually in larger relative amount than in atmospheric air, as it often reaches 32 per cent. The amount of oxygen and carbon dioxide depend so much on varying conditions, such as the amount of exposure to the air, the growth or absence of plant life, and the presence of animals, as to render the proportions absolute and relative, of the gases so variable, that few inferences of hygienic importance can be drawn from their determination. A lessening, however, at one part of its course, in the quantity of oxygen which a certain water is known to contain, may be useful, as pointing out that organic matter has been in the water.‡

28.—*What are the useful gases in water?*

O, CO_2, N, they render water sparkling and pleasant. [O and CO_2 are dissolved by water to a larger extent than N.]

29.—*What useful purposes does O serve in water?*

It serves to gradually oxidise and destroy the decomposing organic matter which may be dissolved or suspended in water. It likewise serves to support the life of fishes and other aquatic animals.

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*See Part XX on PHYSICS AND HYGIENIC CHEMISTRY.

†WHITLEGGE'S *Hygiene and Public Health.*

‡PARKES' *Practical Hygiene.*

30.—*What proportion of oxygen is usually present in*

About 32 per cent. [The quantity of this gas and likewise that of CO_2 depends on the exposure to the air and on the quantity and presence of dead or living organic vegetable and animal matter in the water.]

31.—*Of what use is CO_2 in water?*

It renders soluble the $Ca\ CO_3$, $Mg\ CO_3$, and other constituents which are little or not at all soluble in pure water. [CO_2 likewise serves to nourish green water plants in the same way that it does ordinary green vegetation.]

32.—*What may be considered the usual percentage amount of oxygen, nitrogen, and carbonic acid gas in water?*

Oxygen 30 to 37, nitrogen 63 to 70, and CO_2 8 to 10 per cent.

33.—*What is the total amount of gases in a good palatable water?*

From 25 to 50 c.c. in a litre.

34.—*What is the relation of chlorine to drinking water?*

Chlorine in small quantities occurs in all waters. An undue quantity, unless explained by its coming from a saline spring, or from near the sea, should arouse suspicion. The chlorides in water are important as indications of the existence of human excremental contamination, and sometimes they form a guide as to the channel by means of which sewage gains access. Hence the importance of estimating the amount of chlorine in quantitative chemical analysis. Excess of chloride of calcium and magnesium may give rise to diarrhœa.

35.—*What are the chief sources of excess of chlorine in water?*

(1) Percolation from sea water in sea coast places.

(2) Deep wells (200 or 300 feet) sunk into red and green sandstone strata, chiefly as NaCl; and

(3) Sewage.

[In the first two there is no excess of organic matter. In deep wells there may be ammonia of organic origin from ancient decomposition, and it is therefore harmless; with excess of chlorine from sewage contamination there is always excess of organic matter which is very dangerous.]

36.—*In what form is chlorine chiefly present in water?*

Chlorine is present in water chiefly as a constituent of common salt.

37.—*What is the average amount of Cl contained in good water?*

About 3 parts per 100,000 (de Chaumont). [This amount is of no consequence except perhaps in that it adds to the palatability of the water.]

38.—*What impurities may natural waters contain?*

In suspension—Particles of animal, vegetable, and mineral origin. Microbes and other living organisms, animal and vegetable.

In solution—Gases, mineral salts; soluble organic matter of animal and vegetable origin.*

39.—*What are the primary sources of water?*

The primary sources of all fresh water are the seas and oceans. From them the heat of the sun causes the water to evaporate into the air, in the same way that the water disappears from a tumbler, if exposed to the sun's rays. The oceans are very large, and a considerable quantity of water is drawn up from them in the form of vapour to mix with the air. When the wind blows towards the land, this hot and moist air from over the ocean is driven to a cooler place. Now, when the air gets cold, it cannot hold this water any longer in the form of vapour, clouds form, the little particles of water in the clouds join together and descend. The water which thus drops we call *rain*. The air always contains some of this watery vapour or steam. We see this when, in the hot weather, we put ice into a glass of water. The outside of the glass at first acquires a hazy appearance, and then droplets of clear water accumulate upon it. The cold glass has cooled down the air surrounding it, and caused the moisture in the atmosphere to condense into drops. When it rains hard, the greater part of this rain-water finds its way to the large rivers, and, finally, into the seas and oceans whence it originally came. There is no manufactory of water in the world, the amount always remains the same although the distribution varies.

40.—*What are the chief sources of water for purposes of supplying communities?*

Wells—superficial or shallow, deep, artesian and tube or driven wells; rivers, springs, rain, tanks, lakes, artificial reservoirs; surface waters and ground water.

41.—*What may be said of the quality of these various sources?*

That they are hygienically of very unequal value as sources of supply; for whereas some of them may be without the least suspicion as to being productive of harm to the human economy, others may be occasionally, if not always, dangerous to health and sometimes even to life itself.

42.—*Classify the sources of water-supply, and point out the advantages and disadvantages of the various sources and modes of water-supply.*

Sources of supply may be classified under two main heads:—*surface supply*, from brooks, rivers, lakes, or reservoirs, surface-fed springs, and shallow wells; and *supply from deep subterraneous*

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* WHITLEGGE's *Hygiene and Public Health.*

sources, as from springs cropping out at the foot of mountain ranges, and having deep-seated sources, from artesian wells, and from other deep wells with or without adits or tunnels to increase the supply by tapping water-charged fissures.

All surface supplies will be more or less contaminated by animal and vegetable matter, and, in populous places, from sewage, and by waste from factories. Water collected in reservoirs and mountain lakes, from high-lying uncultivated moorland, will be the purest of these; next in order, water from springs and from brooks not polluted by sewage; and last but worst come shallow wells.

The softness of surface water is an advantage for cooking, washing, and infusing tea, but disadvantageous from its liability to absorb lead from service pipes. Some moorland waters contain acids which may attack lead.

Water from deep-seated sources are generally pure and wholesome, and when drawn from the granitic, hard sandstone, or oolitic sources, it will be soft. Supplies from the chalk-formation will be pure and wholesome but hard, the hardness partially disappearing on boiling. Water drawn from the selenitic rocks is permanently hard and decidedly unwholesome. Gravel and sand beds, and the softer rocks, furnish water of variable quality.

The *modes of supply* are by gravitation and by pumping. Surface waters are supplied by gravitation, though it may be necessary to pump from a river. Water so supplied will generally require filtering. The first cost of the necessary works is large in proportion to cost of erecting pumping machinery.

Water pumped from deep wells may require to go through a process of softening; no filtering will be needed, nor will large reservoirs be required; the working expenses will be considerable, but may not exceed the interest on the capital outlay of an alternative gravitation scheme.

Modes of distribution may be considered under the heads of modes of supply; these are by constant and by intermittent service. The former should be always preferred, as preventing chances of contamination in the mains and in house cisterns, and for convenience in rapidly extinguishing fires. With good house fittings and proper appliances for detecting and preventing waste and leakage, no more water is expended by the constant than by intermittent service, and sometimes less.

In places by the sea-side salt water may be used with advantage for street watering and for baths, and a scanty or expensive supply of potable water economized thereby.*

43.—*As regards water-supply discuss the subjects of:—*

(a) Source; (b) Quantity required; (c) Distribution.

(*a*) If more than one *source* of supply be available, that source be chosen which will furnish not only a good supply of potable water for domestic use, but water of a quality adapted to the special requirements of the prevailing industry. The prosperity of the place may greatly depend upon a suitable class of water being available for special purposes, as for brewing, dyeing, etc.

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* Abstracted from *Sanitary Record*, 1888. The various subjects dealt with cursorily in this answer will be alluded to more in detail in future pages.

These considerations may determine the choice between upland, river, and deep well water. Comparative expense may also have to be taken into account. A gravitation scheme will involve a greater capital outlay, a pumping scheme greater working expenses.

Water of a nature that will act on the leaden distributing pipes should be avoided if possible; if not, it must be specially treated to prevent absorption of lead. Very hard water should be avoided, or water which derives its hardness from unwholesome constituents.

(*b*) The *quantity required* will depend partly upon the nature of the occupation of the people, upon the prevalence or absence of water-closets and baths, and upon the requirements of the manufacturers; and provision should also be made for street watering, public baths, and other public purposes.

The quantity necessary must be determined in each case by careful inquiry and observation; the flow of sewage will afford considerable information. Allowance must be made not only for present but for future requirements, and this will necessitate careful calculations as to the prospective growth of the town.
The requirements will probably average 15 to 20 gallons a head *per diem* for private purposes, and 30 gallons for all purposes.

(*c*) *Distribution* should be on the constant system, with pressure enough to give a supply at all times to the top of the highest buildings. Fire-plugs should be provided in sufficient number for the extinguishing of fires. Manufactories should be supplied by meter.

The system of pipes should be divided into sections, each capable of being isolated from the others, to facilitate the detection and prevention of waste by means of valves to regulate supply, and by waste-detecting meters, supplemented by careful and constant inspection. "Dead ends" as far as possible should be avoided, and the system so arranged as to maintain constant circulation through the mains.*

44.—*What are the different sources of water usually available for town supply? State the advantages and disadvantages of each.*

Rivers, streams, natural springs, artificially-formed wells, and impounding reservoirs or a combination of any of the former. In river supply the advantages consist in its constancy, ease with which it can be collected for filtration, and its general softness; at the same time this is greatly counterbalanced by its liability to contamination, and often costly pumping. Natural springs are generally pure and often so placed as to admit of a gravitation supply (a great feature in a public water supply scheme), though sometimes the water is hard; their disadvantage is their liability to dry up or cease to yield in seasons of drought.

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* Abstracted from *Sanitary Record*. *Vide* foot-note, p. 13.

Artificially-formed wells, if carried down to good water-yielding strata, are excellent sources of supply. The greatest care must be taken both in the construction of the well itself and in the selection of the site, as a well may often be found to yield a good supply for some time and then to almost fail. The water is generally hard, which is a disadvantage for domestic purposes.

45.—*How would you classify waters in regard to their freedom from organic matter?*

"In respect of freedom from that most objectionable of impurities, organic matter ('organic carbon' and 'organic nitrogen'), waters range themselves in the following order of merit:—

1. Spring water,
2. Deep well water,
3. Rain water,
4. Upland surface water,
5. Shallow well water."*

46.—*From what formations do we get the purest water supplies?*

Granitic, millstone grit, hard oolite, and chalk.

47.—*Is there any connection between impure water and epidemic disease?*

Yes; so close indeed is the connection between certain epidemic diseases and impure water that it may be stated that such diseases can scarcely spread widely in a community without its influences; for instance, it is a safe thing to assume that any severe outbreak of "bowel complaints," enteric fever or cholera in a community, should call the attention of the sanitary authorities to the state of general water-supply.

48.—*What substances ought to be absent from drinking water?*

The following substances ought to be absent or present only in traces in drinking water:—HNO_3, HNO_2, NH_4 salts, metallic salts, organic matter, alkaline sulphides, and H_2S.

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* FRANKLAND'S *Water*

49.—*Give the substances with their quantities admissible in a good drinking water ?*

Cl under 2 grains per gallon.
Lime „ 3 to 4 „ „ (except in chalk water).
Mg only a trace.
Phosphates „
Sulphates „
Total solids under 8 grains per gallon.
Volatile „ 1 „ „
Free ammonia under ·0014 „ „
Albuminoid ammonia under ·0056 per litre.
Oxygen for oxidisable organic matter below ·035 gramme per litre.
Fixed hardness under 20 degrees.

Exceptions are made in the cases of chalk water, where lime may be in excess, and in NaCl and H_2CO_3 waters, if the salts are inorganic.

Anything beyond above contained in a water removes it from the category of first-class waters.

50.—*What are the chief impurities met with in water, and what in general terms, are their effects ?*

The most frequent impurity is sewage matter, and the next, percolation of refuse matter of different kinds from sinks, ashpits, etc.; impurities from graves of men, and animal impurities from manufactories and slaughter-houses. An increase of mineral matter dissolved or suspended is only of subordinate importance, whilst increase of HNO_3 or NH_3 is only evidence of previous contamination of a dangerous kind, but *no proof by themselves* of existing danger. Any notable increase in oxidisable organic matter or organic suspended matter, whether organised or not, is always gravely suspicious.

Excess of fixed lime salts and magnesium salts is apt to produce dyspepsia and diarrhœa occasionally, and to aggravate dysentery and affections of the mucous membrane generally, especially among the aged and in delicate children. Magnesium salts, some think, give rise to goître, others consider that disease to be due to alkaline sulphides. Suspended mineral matter, such as scales of mica, silica, etc., may cause diarrhœa. Some alkaline chlorides, carbonates and sulphates may be present without producing any evil effect.*

If we find a good deal of organic matter and only a small quantity of chlorine, we as a rule conclude that *sewage* in the solid or liquid form has not been the cause, but that in all likelihood the sources of impurity is vegetable matter. The chlorides affords a guide as to the source of contamination.

It is a question whether the dissolved or suspended organic matter is the more dangerous. There are reasons to suspect the suspended, and if we accept the "germ theory of disease," this would be a necessary conclusion. Yet it would be very rash to assert that the dissolved organic matter could be held blameless.

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* This subject is dealt with in detail in the Chapter on the DISEASES PRODUCED BY IMPURE WATERS.

51.—*What is the inference to be drawn from the presence of vegetable and animal organisms in water?*

Living organisms of all sorts and descriptions, both animal and vegetable, are frequently met in water. Their very presence naturally indicates the existence of a suitable food, which food is chiefly organic. They do not of themselves, however, always entitle us to absolutely condemn the water in which they are found.*

52.—*Is it difficult to tell whether a particular natural water is or is not fit for general use?*

As a general rule, it is not difficult to decide whether a natural uncontaminated water is or is not suitable for general use. With reference to most of the substances which occur naturally in potable waters, it is hardly fair to designate them as "impurities," because these substances are common to all natural waters, and there is more or less of stigma conveyed in the term "impurity." Fairly to be designated as impurities, however, are mineral substances of known poisonous character and the organic matter of animal or vegetable origin which come as refuse from manufacturing or from household operations.†

53.—*How does organic life affect the quality of water?*

Fishes and certain aquatic plants increase the purity of water.

54.—*Write some practical hints on the subject of search after a source of water supply?*

[In this respect the following abstract on the *search after water* from PARKES' *Practical Hygiene* cannot be improved upon.]

"Few precise rules can be laid down in regard to a search after a water-supply. On a plain, the depth at which water will be found will depend on the permeability of the soil and the depth at which hard rock or clay will hold up water. The plain should be well surveyed; and, if any part seems below the general level, a well should be sunk, or trials made with Norton's tube wells. The part most covered with herbage is likely to have the water nearest the surface. On a dry sandy plain, morning mists or swarms of insects are said sometimes to mark water below. Near the sea, water is generally found; even close to the sea it may be fresh, if a large body of fresh water flowing from higher ground holds back the salt water. But usually wells sunk near the sea are brackish; and it is necessary to sink several, passing farther and farther inland, till the point is reached where the fresh water has the predominance.

"Among the hills the search for water is easier. The hills store up water, which runs off into plains at their feet. Wells should be sunk at the foot of hills, not on a spur, but if possible at the lowest point; and if there are any indications of a water-course, as near there as possible. In the valleys among hills the junction of two long valleys will, especially if there is any narrowing, generally give water. The outlet of the longest valley should be chosen, and if there is any trace of the junction of two water-courses, the well should be sunk at their union. In a long valley with a contraction, water should be sought for on the mountain side of the contraction. In digging at the side of a valley, the side with the highest hill should be chosen.

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* HEHIR's *Hygiene of Water and Water-Supplies*. (Thacker Spinck & Co., Calcutta, 1890.)

"Before commencing to dig, the country should be as carefully looked over as time and opportunity permit, and the dip of the strata made out if possible. A little search will sometimes show which is the direction of fall from high grounds or a watershed. If moist ground only is reached, the insertion of a tube, pierced with holes, deep in the moist ground, will sometimes cause a good deal of water to be collected. Norton's American tube-well gave satisfaction in Abyssinia, although it did not succeed so well in Ashantee. A common pump will raise the water in it if the depth be not more than 24 or 26 feet; if deeper, a special force pump has to be used."

55.—*What are subterranean reservoirs?*

They are the underground basins or magazines which store up the waters of the great rain percolations, and deliver them to the springs or wells in constant flow, as surface lakes gather the floods and feed the streams with an even, continuous, delivery. A concave dip of a porous stratum lying between two impervious strata presents favorable conditions for an "artesian" well, especially if the porous stratum reaches the surface in a broad, concentric plane of great circumference around the dip, forming an extensive gathering area.

Waters are sometimes gathered through inclined strata from very distant watersheds, and sometimes their course leads under considerable hills of more recent deposit than the stratum in which the water is flowing.

The chalks and limestones do not admit of free percolation, and are unreliable as conveyers of water from distant gathering surfaces, since their numerous fissures, through which the water takes its course, are neither continuous nor uniform in direction.

56.—*Is dew ever used as drinking water?*

It has been used on boardship when the supply has run short, and no distilling apparatus is available. It has likewise been used by travellers in the desert and sterile regions of South Africa and Australia, and, it is said, in Chili and Peru.

57.—*What are the characters of snow-water?*

Snow-water contains the salts of rain-water, with the exception of rather less ammonia. The amounts of carbonic acid and air are very small. It is clear, but heavy, insipid and unpalatable.

58.—*What changes in regard to purity and quality take place in the freezing of water?*

In freezing, water loses most of its impurities, and any incorporated vegetable organisms present are temporarily rendered inactive, but on melting, they once more resume their vital properties. It becomes purer, through the disappearance of almost all its mineral constituents, including much of the calcium carbonate and sulphate (if present) while its contained air and other gases are largely expelled. Even most of the substances dissolved in the water disappear from the ice. The water resulting from the melting of ice is usually pure, heavy, and non-ærated.

We have more than once analysed ice from large factories and found it to be very impure, containing a considerable amount of organic matter, including micrococci and bacterioid forms. The most dangerous impurities of water are, suspended organic matters and some of those contained in the water before freezing is retained in the ice. Dead organic matter, if in large quantity, is decidedly unwholesome, but even in small quantities, it is usually dangerous, because it increases the probability of contamination with dangerous living organisms. It is highly important therefore that in the manufacture of ice for human consumption the water employed should be pure. It is but fair to say, however, that most factory-ice is pure.

59.—*What are the properties of natural and artificially prepared ice and why is it important to be familiar with these properties?*

Natural ice results from the freezing or crystallization of rain-water or snow. On melting it yields an exceedingly pure water. During the freezing process it gets rid of the gases and most of the mineral and of much organic impurities contained in the water previously. The absence of gases and almost all mineral matter renders it insipid, and devoid of that freshness and sparkle so much appreciated in wholesome water. The absence of saline matter renders it soft. Artificially prepared ice may also yield pure water, but should the water from which it is prepared be of doubtful quality, it should not be consumed. As a considerable quantity of artificially prepared ice is now consumed all over the civilised world, its quality is of grave importance.

Where the quality of the water used in the preparation of ice is not guaranteed, it is infinitely safer to use the ice as a cooling agent, by placing the vessel containing the beverage to be cooled in it, rather than placing the ice in the beverage.

60.—*Is the water from melted snow pure?*

Yes, if the snow is collected remote from human habitations. Near dwellings, however, it is liable to contain much organic matter. [The great outbreak of cholera in the year 1832, in Moscow, was due to the people consuming the snow upon which had been thrown the dejecta of cholera patients.]

61.—*Is snow-water wholesome or otherwise?*

There has long been an opinion that snow-water is unwholesome, but this, if it be true, is probably due to impurities. It is certainly unpalatable and unpleasant to the taste and is said to cause gastric disorders. Ice and snow may contain much suspended organic matter. Dr. Baker Edwards, of Montreal, found three parts per 100,000 in the shore ice and in the river ice. In Northern Europe the poorer classes have the habit of using the snow lying about their dwellings, and as this is often highly impure with refuse substances thrown out from the house, this water may be unwholesome. It has been conjectured that the spread of cholera in the Russian winter of 1832 was owing to the use of such snow-water contaminated by choleraic excretions. A large number of the cases which occurred in Moscow in that year were traced to people who had consumed the melted water of snow upon which latter cholera discharges had been thrown. Ice and snow may also be the means of conveying malarious poison to places at a distance.

62.—*What are the characters of surface and subsoil waters?*

They are very variable in composition, but often very impure, and always to be regarded with suspicion. Heaths and moors, on primitive rocks, or on hard millstone grit, may supply a pure water, which may, however, be sometimes slightly coloured with vegetable matter. Cultivated lands, with rich manured soils, give a water often containing both organic matter and salts in large quantities. Some soils contain potassium, sodium, and magnesium nitrates, and give up these salts in large quantity to water. This is the case in several parts of India. In towns and among the habitations of men, the surface water and the shallow well water often contain large quantities of calcium and sodium nitrites, nitrates, sulphates, phosphates, and chlorides. The nitrates in this case probably arise from ammonia, ammonium nitrite being first formed, which dissolves large quantities of lime. Organic matter exists often in large amount, and slowly oxidises, forming ammonia and nitric acid. In some cases butyric acid, which often unites with lime, is also formed.

63.—*How is this surface water affected by passing through the soil of inhabited areas?*

This surface water in passing over and through the filthy ground around habitations, carries with it many poisonous matters. We see, therefore, that in the case of superficial wells, the quality of the water they supply depends upon the nature of the soil through which the subsoil water flows. This soil has, as a rule, been contaminated by the organic impurities of years. Now, until all the vegetable and animal organic matter of the soil is oxidised (a process that takes years to complete), the water from superficial wells remains impure: but in the absence of proper soil and surface drainage, the pollution of the soil is constant and progressive, and therefore this oxidation of organic matter is never completed.*

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* Vide AUTHOR'S *Hygiene of Water and*

[The water of some of the superficial wells we have analysed is really a form of dilute sewage.]

64.—*Does surface water contain much CO_2?*

As a rule it is very poor in CO_2.

65.—*What does excess of CO_2 in water usually indicate?*

That the water has come from a considerable depth.

66.—*What is meant by upland surface water?*

The water collected in hilly districts as on moorlands at the head of a river.

67.—*Is upland surface water from uninhabited areas good as a source of supply?*

Yes, probably one of the best

68.—*What other waters may we include in upland surface waters?*

The waters from all the lakes in mountainous districts.

69.—*What form of organic matter may be found in upland surface water?*

Peaty matter is frequently present in such water often giving the water a decidedly yellow hue

70.—*How may the peaty matter be removed?*

By filtering the water through beds of sand.

71.—*Is peaty matter dangerous and is filtration absolutely necessary?*

No, it is quite innocuous, although the colour gives the water an unpleasant and uninviting appearance, besides being unpalatable. The filtration of such water is more a matter of expediency than of necessity. Almost all the water supplies in Ireland from upland surface districts contain peaty matter.

72.—*What is the source of danger in connection with filtered peaty water?*

Water impregnated with peaty substance is charged with dissolved organic matter, mostly of vegetable origin; in its native rivulets it is kept sweet by the presence of myriads of organisms, together with abundance of green plants. When such water is separated from these larger forms of living population, as is done by straining through sand filters, the organic matter in solution soon begins to decompose.

73.—*Is the effluent from irrigated lands pure or otherwise?*

The *effluent* from *irrigated land*, particularly that from rice-fields, is exceedingly impure and dangerous to use for drinking purposes. In some agricultural districts, this water forms the principal source of supply. These fields are regularly manured and contain decaying vegetable and animal matter. The combination of putrefying animal and vegetable organic matter in such water is most pernicious to the well-being of those who drink it.

74.—*What are the characters of the water of ditches, pools, and ponds?*

The water of ditches, pools and ponds, is excessively impure, especially if close to human habitations. It is usually stagnant, foul, and laden with organic matter, including living organisms, animal and vegetable Its consumption is always associated with great danger to health, and if its use is unavoidable, it should be filtered, repeatedly boiled, and filtered again before being used for drinking purposes. In this case there must be two filters. [We have seen villages depending entirely for their water-supply on ponds and the water contained in shallow excavations, and we have recorded the coincident high mortality in such villages.]

75.—*What is "under drainage" water? Is it a good water?*

Water which has filtered through the soil and has been collected from drains laid from 3 to 6 feet under the surface. It is often a tolerably pure water, except, of course, when it is from manured cultivable land.

76.—*What is alluvium?*

It is usually a mixture of sand and clay.

77.—*What are the characters of alluvial waters?*

They are generally more or less impure and are exceedingly variable in quality and in constituents, containing calcium carbonate and sulphate, magnesium sulphate, sodium chloride and carbonate, iron, silica, and often much organic matter. Occasionally the organic matter oxidises rapidly into nitrites, and if the amount of sodium chloride is large, it might be supposed that the water had been contaminated with sewage. The amount of solids per 100,000 parts varies from 30 to 180 parts, or even more. Occasionally the organic matter rapidly oxidises into nitrites.

78.—*What are the characters of waters from marshes?*

The water of *marshes* is one of the most unwholesome that can be used. It is decidedly impure, containing an abundance of decaying vegetable matter (from 10 to 40 grains per gallon), although it sometimes has the appearance of being pure. There is often much suspended organic matter; and the salts are scanty—except the marsh be adjacent to the sea—and consist mostly of carbonates, sulphates, and chlorides of sodium and lime. It is invariably a suspicious water. [The vegetable matter of marsh waters, in combination with heat and moisture, is the cause of "malarial" diseases"—ague, remittent fever, enlarged spleen, dysentery, diarrhœa, anæmia and sometimes neuralgia. Such water should never be drunk. If compelled to use it, we should first give it a series of boilings and then filter it.]*

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*HEHIR's *Hygiene of Water and Water Supplies.* (Thacker Spinck & Co., Calcutta.)

79.—*Has the course pursued by water in its passage through the various underground geological strata any importance with regard to its chemical composition?*

Yes; the nature of the geological strata through which the subterranean water feeding a well, or other source of water supply flows, has an important bearing upon the mineral and gaseous constituents of that supply, and in rendering them palatable, colourless and wholesome by percolation.

80.—*What are the characters of soft and stone rock waters?*

They are very variable in quality, so that no average can be drawn. Their total solids range from 25—80 grains per gallon, and consist of carbonate, sulphate, and chloride of sodium, small quantities of lime and magnesia, and a large amount of organic matter.

81.—*What are the characters of loose sand and gravel waters?*

They vary much in composition, but they are occasionally very pure, especially those from *green* sand. In this latter case the total solids are not more than "from 4 to 8 grains" per gallon and consists of a little sodium carbonate, sulphate and silicate; magnesium carbonate; sodium and magnesium chlorides.

82.—*What are the characters of millstone-grit, and hard oolite waters?*

They are generally very pure, the solid constituents small, not exceeding eight grains to the gallon, and consisting chiefly of the sulphates and carbonates of lime and magnesia, with a trace of iron and potassium chloride; sodium and potassium sulphate; and traces of organic matter. In tolerably pure gravels, not near towns, the water is very free from impurity. In the case of many sands, however, which are rich in salts, the water is impure, the solid contents amounting sometimes to 50 or 70 grains per gallon or more. As a rule, they contain much mineral matter derived from the sand (chiefly calcium, magnesium, and sodium salts), as well as considerable quantities of organic matter. They are often of alkaline reaction and may contain a good deal of organic matter. They are occasionally very impure in consequence of the ease with which surface water may permeate the surface soil to reach the water-bearing stratum below.

83.—*What are the characters of water from granite, metamorphic, clay slate and trap-rock formations?*

These waters are generally very pure and wholesome, containing small quantities of solid constituents, mainly carbonate and chloride of sodium, with a little lime and magnesia. "Generally the granite water is very pure, often not exceeding 3 to 9 parts per 100,000 of solids, consisting of sodium carbonate and chloride, and a little lime and magnesia. The organic matter is in very small amount. The clay slate water is generally very pure, often not containing more than from 4 to 5 parts per 100,000. The water from hard trap-rocks is pure, but if the trap be disintegrated the shallow wells sunk in it are of course liable to be fouled by surface washings or soakage."*

84.—*Why are greensand waters pure?*

The greensand are porous and oxidising strata, containing, however, protoxide of iron, which exerts a reducing action upon nitrates and nitrites in the water, converting them into ammonia, and reducing sulphates with the resulting formation of sulphuretted hydrogen. These waters are organically very pure, in this respect in fact, comparable with distilled water, but as it often passes over or through chalk, it may be very hard. Deep wells sunk in such strata are pure but hard. The hardness which is due to bicarbonate of calcium is temporary and can be removed by boiling (as in the case of chalk waters).

85.—*Why are new red sandstone waters pure?*

The new red sandstone, being a porous and ferruginous rock, acts as a powerful filter and oxidiser upon the organic matter in the water that percolates through it.

86.—*What are the characteristics of waters from lias clay?*

Lias clays yield water of variable composition, but they sometimes contain from 80 to 220 grains of mineral matter to the gallon, with a small quantity of organic. They are often excessively impure, and in a specimen examined by Prof. Voelcker, 88 grains of sulphate of lime and 41·8 of magnesium sulphate were found.

87.—*What may be said with regard to the quality and yield of clay waters?*

"Very few springs exist in the stiff clays; the water is chiefly surface, and falls soon into the rivers; it varies greatly in composition, and it often contains much suspended matter, but few dissolved constituents, chiefly calcium and sodium salts."

88.—*What are the characters of selenetic waters?*

Selenetic waters are unwholesome. They are hard, very little affected by boiling, containing excess of sulphate of lime (6 to 20 grains or more per gallon). They give rise to dyspepsia, and to constipation alternating with diarrhœa. They are not good for cooking or washing.

89.—*What is the relation of lime and magnesian salts to the various kinds of drinking water?*

The *calcareous and magnesian salts* are the most frequent mineral matters met with, and of these the sulphates and carbonates are the chief to be dealt with. *Chalk* (or carbonate of lime) is only soluble to the extent of two or three grains to the gallon in chemically pure water; but it is readily dissolved by the carbonic acid present in all natural waters. Ordinary limestone and marble are varieties of carbonate of lime. Gypsum, alabaster, and selenite are varieties of the *sulphate* of the same metal. The sulphate is far more soluble than the carbonate, but is less diffused in the soil, and so is not met with in similar quantities. The amount of lime salts in water varies from one-third of a grain to the gallon (in lakes surrounded by siliceous mountains), to 15 or 20 grains per gallon in many well waters, specially those in chalky districts. It has been supposed that the lime salts of water contribute to the formation of bone of animals, but it is usually in such small quantities as to have no material effect in this respect; and, further, Nature furnishes in ordinary food a much more convenient and suitable method of bone formation, than this. Even in places where large amounts of salts of lime are met with, no conspicuous influence is seen in the consumers—either the people become accustomed to the water, or the quantity of lime in it has no particular effect upon them.

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* PARKES' *Practical Hygiene, 7th Ed.*

The *magnesian salts* are met with almost as commonly as the calcareous. Well water usually contains about 2½ or 3 grains to the gallon. It occurs as a carbonate with smaller quantities of the sulphate. These quantities have no effect on health. Some of the aperient mineral waters contain large quantities of sulphate of magnesium or Epsom salts. Excess of sulphate of lime and magnesia (10 to 20 grains to the gallon) may constitute an impurity.

90.—*What is dolomite?*

Dolomite or magnesian limestone, is a double carbonate of lime and magnesia.

91.—*What are the characters of limestone, and dolomite waters?*

They are wholesome and agreeable, bright and sparkling as a rule, but characterised by a larger amount of total solid matter than chalk water, and by the presence of a great quantity of sulphate of lime (4 to 12 grains or more) and some carbonate of lime and much magnesium carbonate and sulphate. They are hard waters, and this hardness is much less affected by boiling than is the case with the chalk waters, and are therefore less suited for culinary and domestic purposes. Such waters may possess purgative properties. The organic matter is usually very small in amount..

92.—*What are the chief characteristics of chalk waters?*

Chalk waters are clear, wholesome, sparkling (being charged with carbonic acid gas), and pleasant, and generally very pure. They are chiefly characterised by the solid matter, which consists of carbonate of lime (5—20 grains to the gallon), a little carbonate of magnesia, small quantities of common salt, and insignificant amounts of iron, silica, potassium salts, phosphoric and nitric acids. They are as a rule very pure organically. They are hard, but the hardness is removeable by boiling, which drives off the carbonic acid gas, holding the excess of carbonate of lime in solution. The hardness may likewise be removed by Clark's method.

93.—*Occasionally chalk water contains very little chalk, why is this?*

Because sometimes the water drawn from the upper part of the chalk is really derived from tertiary sand lying above the chalk.

94.—*When this is the case what other bodies take the place of the chalk?*

The decrease in chalk is associated with a comparatively large amount of carbonate and chloride of sodium, and the water may actually be alkaline in reaction.

95.—*What are the advantages and disadvantages of chalk waters?*

They are as a rule wholesome and sparkling, but from the large quantities of $CaCO_3$ contained, they are very hard and, therefore, possess all the disadvantages of hard waters.

96.—*What is the special distinction in connection with chalk waters?*

They are very hard.

97.—*Give a table showing the relation between the general characters of a water, and the geological strata from which it is derived.*

Chalk ...	Clear, wholesome, and sparkling; generally very pure, and chiefly characterised by the solid matter, consisting almost entirely of carbonate of lime
Limestone and dolomite.	Wholesome and agreeable, but characterised by a larger amount of total solid matter than chalk water, and the presence of a greater quantity of the sulphate of lime and magnesia.
Millstone, grit and hard oolite.	Generally very pure; the solid constituents small, and consisting chiefly of the sulphates and carbonates of lime and magnesia with a little iron.
Granite, metamorphic, trap-rock and clay slate formations.	Generally very pure, small quantities of solid constituents, mainly carbonate of soda and chloride of sodium, with a little lime and magnesia.*

98.—*How much $CaCO_3$ does chalk waters contain?*

About 1¼ tons in every 100,000 gallons.

99.—*What are the most common mineral constituents of water?*

Carbonate and sulphate of lime.

100.—*How may we explain the presence of carbonates of lime and magnesia in certain waters?*

Neither carbonate of lime nor carbonate of magnesia is dissolved by pure water to any considerable extent; if, however, the water be charged with carbonic acid gas, its solvent power is very much increased and a considerable quantity of the carbonates will pass into solution. This is generally explained by supposing that there is an actual chemical combination between the carbonic acid and the carbonate of lime, forming what is called a *bi*-carbonate. Since meteoric water, in its passage through the air and ground, always absorbs carbonic acid, and since carbonate of lime is widely diffused as limestone, marble, chalk, etc., in the soil, it is not surprising that many natural waters are hard on account of the dissolved bicarbonate of lime.

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* HUSBAND's *Handbook of Forensic Medicine and Medical Police.*

101.—*Is the quality of hardness peculiar to chalk waters?*

No; hardness is not peculiar to water from any one source; rivers and lakes, springs and wells, are all liable to furnish hard water when they are situated in regions which contain deposits of limestone or of gypsum or of magnesium minerals.

102.—*Discuss the subject of hardness of water?*

The solutions of salts of lime and magnesia are among the chief causes of the quality called hardness in water. Their carbonates are broken up by boiling, for the heat dissipates the carbonic acid, when the insoluble bases are deposited, and, with such other insoluble matters as are present, form incrustations such as are seen on the interior of tea-kettles and boilers where hard waters have been heated. The carbonates, in moderate quantities, are less troublesome to human constitutions than to steam users. The effects of the carbonates are termed "temporary hardness." The sulphates, chlorides, and nitrates of lime and magnesia are not dissipated by ordinary boiling. Their effects are therefore termed "permanent hardness."

This source of waste from hard waters, which extends to the destruction of many valuable food properties, as well as to destroying soap, is not sufficiently appreciated by the general public.

One of the first results of the massing of people together is an increase in degree of fertilization of the land of their neighbourhood, and thus the lands over and through which their waters flow are mixed with concentrated decomposing vegetable and animal products. The continued increase in the hardness of well-water as the population about them becomes more dense, indicates that this increase is due to the salts of the dissolved organic refuse with which the ground in time becomes saturated.

103.—*Give examples of very hard and very soft waters.*

VERY HARD.	VERY SOFT
Sunderland, from dolomite, 30° hardness.	**Distilled water.**
Chatham, 24°.	**Rain water.**
Croyden & Kent Company's water, 20—21°.	**Upland surface water.**
Chalk and selenetic waters.	

104.—*What are the best geological formations to give water a bright and sparkling appearance and yet maintain their purity?*

Chalk formations, hard oolite, greensands, and new red conglomerate sandstone.

105.—*What change is produced by adding carbonate of soda to water containing bi-carbonate of lime?*

The chemical effect of adding carbonate of soda to the bicarbonate of lime is to form bicarbonate of soda, which is soluble in water, and carbonate of lime, which is practically insoluble, and which, by this means, is removed to a large extent from the water and settles as a fine powder if the water is allowed to stand.

106.—*What forms the crust in the interior of kettles and boilers?*

The bulk of the crust is made up of carbonate of lime, and to a less extent by carbonate of magnesia.

107.—*What are the causes of the mineral incrustations in steam boilers?*

The water in the boiling process has all its free and any excess of CO_2 driven off and the salts, especially the carbonates of lime and Mg if held in solution, are deposited. Further, the gradual decrease in the bulk of the water (in consequence of the evolution of steam) renders it unable to hold the salts dissolved in it as solution any longer.

108.—*How does hard water affect the cooking of meat and vegetables?*

When meat or vegetables are cooked by boiling in hard water, a certain amount of the same material as is deposited on the surfaces of boilers and kettles, coats the meat or vegetables and either hinders the proper penetration of the heat into the interior, or prevents solution of the soluble materials when this is desired. The same applies to the infusion of tea. The fur lining is also a non-conducting material, and prevents the passage of heat from the fire to the contents of the boiler or kettle, thus causing a waste of fuel.

109.—*How does hard water or water containing iron affect the infusing of tea, and how may such waters be rendered fit for that purpose?*

If water contain much lime or iron it will not make good tea; in each case the water should be well boiled with a little carbonate of soda for 15 or 20 minutes, and then poured on the leaves.

If lime salts be the cause of the hardness the particles are precipitated upon the leaves and iron forms a tannate of iron in the tea.

110.—*From a sanitary point of view which is the most desirable, hard or soft water?*

Although it may be an open question as to the effect of drinking hard water, there is no doubt but that, on other sanitary grounds, soft water is much to be preferred, and especially with reference to cleanliness of person and of surroundings. Hard water is not only less agreeable in washing, but is less effectual as a cleansing agent. A portion of the soap used is destroyed for all practical purposes, and forms in the water an insoluble curd, useless as a detergent and unsightly to the eyes of those who are accustomed to soft water. For cooking, hard water is, as a rule, much less suited than soft, and if, in addition to these considerations, we take into account the fact that for most manufacturing operations soft water is desirable, it is evident that, for the general purpose of town-supply, soft water is to be preferred.

111.—*What may be said as to the superiority of soft over hard water for washing, cooking, and manufacturing operations.*

The washing of linen can only be performed with soft water. If the available water be hard, it must be artificially softened—an operation which, on the domestic scale must be performed at great expense by the aid of either fuel, soda, or soap. In personal ablution, also, the use of soft water is much more pleasant and efficient. It is also more economical; but, by the general use of a very small quantity of water, the waste of softening material is here much less than in a laundry.

112.—*How would you represent the pecuniary loss in the use of a hard as against that of a soft water?*

Each degree of hardness implies the waste of about 12 lbs. of the best hard soap for each 10,000 gallons or 100,000 lbs. of water used in washing.

The cost of softening 1,000,000 gallons of chalk-water, having a temporary hardness of 20° is:—

	s.	*d.*
16 cwt. of lime @ £ 1 per ton	16	0
Labour.	7	0.
Total... £1	3	0

About 10*s*. of this £1 3*s*. is recoverable in the sale of "whiting" produced in the softening process.

113.—*What are the chief disadvantages associated with the use of hard water.*

(1) The waste of soap in washing clothes.

(2) The difficulty of cooking food, especially vegetables, in it. **Tea** can be but imperfectly infused in hard water.

(3) The precipitation of the lime salts on the interior of vessels in which such water is boiled; or upon clothes or other material coming into contact with the water.

[It is a well-known fact that crude carbonate of soda is used in some laundries in England, and in certain places in India, to lessen the hardness of water, and it is further known that this saturation of clothes with soda decreases the durability of the fabric of clothes. Hard water results from the originally soft rain water falling on, or coming into contact with, limestone rocks, or from the water percolating through strata containing lime, magnesia, iron, and various sulphates, all of which impart hardness to water. Hardness due to carbonate of lime and magnesia kept in solution by excess of carbonic acid, is removed on boiling. The boiling drives off the carbonic acid which kept these salts in solution. This is particularly the case with chalk waters, for on boiling the chalk is precipitated: the hardness it causes is temporary. The sulphates of these salts are not affected in this way].*

114.—*Why is the hardness caused by the presence of bicarbonate of lime (or magnesia) called "temporary"?*

Because it may be removed by boiling. [Some waters are said to have "permanent" hardness; they are not softened by boiling or by Clark's process, and the hardness, is generally due to the presence of sulphate of lime (gypsum) although the sulphate, and other soluble compounds of magnesium, have the same effect.]

115.—*What is the action of common soap on hard water?*

If common soap be added to the water, the water seems to curdle, but refuses to form a froth or "suds," until, by the mutual action of soap and bicarbonate of lime on each other, the lime is nearly all converted into an insoluble lime-soap which forms the curd alluded to. After this point is reached, any additional soap becomes available for washing.

116.—*What is the disadvantage of this method of softening?*

It is an expensive process.

117.—*Mention another domestic method of softening water often employed.*

That of adding ordinary carbonate of soda ("washing soda," "soda crystals") to the water.

118.—*Mention another method of softening water containing excess of carbonate of lime.*

A simpler method consists in boiling the water for half an hour or more. The boiling causes the expulsion in the form of gas of the carbonic acid, the presence of which enables the water to dissolve the carbonate of lime; when this carbonic acid is driven off, the carbonate of lime remaining, settles out as a fine white powder. The deposit which settles from the boiling water adheres more or less to the bottom and sides of the vessel in which it is boiled, and often causes serious trouble in steam-boilers. (*Vide* Nos. 108 and 109).

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* See the AUTHOR'S *Hygiene of Water and Water Supplies.*

119.—*Upon what does the relative expense of Clark's process depend?*

The relative expense of Clark's process depends upon the facilities for disposing of the "whiting" produced. In some localities it would be readily disposed of and pay a large proportion of the expense of softening the water; in other localities it would probably not find a market.

120.—*Is there any economical process which is practicable on the large scale for softening hard waters?*

There is not, and in general terms it may be stated that a water which has a high permanent hardness is unsuited for general use.

121.—*How may hard waters be softened on the small scale?*

By carbonate of soda, which acts upon the soluble sulphate of lime, converting it into carbonate of lime, which, as we have already seen, is nearly insoluble in water. The effect of hard water upon soap, is the same as that of a water the hardness of which is due to the presence of bicarbonate of lime, but there is a considerable difference in the character of the deposit or incrustation which is formed in steam-boilers.

122.—*What simple means might be adopted to soften water?*

The addition of lime, or the use of $Na_2 CO_3$ or of soap.

123.—*Classify the causes of hardness of water?*

The causes of hardness may be thus classified:—

Total hardness due to	1. Carbonate and sulphate of lime and magnesium	
	2. Carbonic acid.	
	3. Calcium fixed salts.	
	4. Other magnesium salts.	
	5. Iron salts.	
	6. Other acids and acid salts of metals.	
Fixed hardness due to	1. Calcium fixed salts.	
	2. Magnesium fixed salts.	
Temporary hardness due to	1. Carbonate of lime and magnesium	in solution.*
	2. Carbonic acid	

[The carbonates at times are fixed salts as in the case of trough water. But when we speak of fixed hardness, we usually mean sulphate of lime and magnesia.]

124.—*From the foregoing statements what are the chief causes of hardness in water?*

Carbonates of lime and magnesium, sulphates of the same metals, acids, and iron.

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* HEHIR'S *Hygiene of Water and Water Supplies.*

125.—*What are the hardest natural waters?*

Those of springs rising in the dolomite, chalk and limestone; the former from containing magnesia is permanently hard.

126.—*Is a small amount of calcium and alkaline salts injurious?*

No, calcium salts in small quantities and alkaline salts, especially Na Cl, in water is not unwholesome, and probably they are valuable constituents, of water. [Water which has a saltish taste, usually due to excess of Na Cl, is said to be "brackish".]

127.—*What are the worst kinds of saline impurities in water?*

Salts of calcium and magnesium.

128.—*What should be the proportion between temporary and permanent hardness?*

If there be a total hardness of 12 degrees, then 7 or 8 of this should be temporary and the remainder permanent, and the same holds good for the higher proportions.

129.—*How much carbonate of lime can a gallon of distilled water dissolve?*

From 2 to 3 grains. [The presence of CO_2 in the water will enable it to take up from 12 to 20 grains of the calcium carbonate.]

130.—*What would be considered an average water in respect of hardness?*

A water containing 8 to 10 grains of mineral matter per gallon, which is equivalent to that quantity $Ca\ CO_3$.

131.—*What is a soft water?*

One containing less than six grains of mineral matter to the gallon, which is equivalent to that quantity of $Ca\ CO_3$.

132.—*What is a hard water?*

One containing 14 or more grains of mineral matter to the gallon.

133.—*What salts cause permanent hardness?*

Sulphates, chlorides and nitrates of the earthy metals.

134.—*Classify waters according to their hardness?*

From *hard* to *soft* we have:—

Shallow well water,
Deep well water,
Spring water,
River water,
Surface water from cultivated land,
Upland surface water,
River water,
Distilled water.

135.—*What is meant by total and permanent hardness?*

The hardness of unboiled water is called *total* hardness, while that of boiled water is called *permanent* hardness.

136.—*What is meant by temporary hardness?*

The hardness that may be got rid of by boiling or by means of Clark's or any other softening process.

137.—*How is the extent of hardness usually calculated?*

Hardness is usually reckoned as so many grains of chalk or carbonate of calcium per gallon of water, or so many parts per 100,000.

138.—*How much solid matter is there in sea-water?*

Thirty-five parts per 1,000.

139.—*How much of this is common salt?*

Twenty-eight parts.

140.—*State briefly how much chloride of sodium is there in sea-water?*

There are 28·05 parts of NaCl in 1,000 parts of sea-water, or 2,805 parts in 100,000.

141.—*What is the composition of sea-water?*

The following are analyses of water taken from the British Channel and the Mediterranean Sea:—

	British Channel.	Mediterranean.
Water	963·74	962·34
NaCl	28·05	29·42
Potassium Chloride ...	0·76	9·50
Magnesium Chloride ...	3·66	33·20
„ Bromide ...	0·02	0·50
„ Sulphate ...	2·29	2·47
Calcium Sulphate ...	1·41	1·35
„ Carbonate ...	0·03	0·11
Iodine	traces	0·00
NH_3	traces	00·00
Ferric Oxide... ...	0·00	00·00

142.—*Does coal gas ever find its way to water supplies?*

Yes; coal gas passing into the ground from leaking gas pipes sometimes finds its way into wells, or even into water pipes. In Berlin, in 1864, out of 940 public wells, 39 were contaminated by admixture with coal gas. A good instance is related by Mr. Harvey where the main pipes were often empty and gas penetrated into

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* Parkes' *Practical Hygiene*, 7th Ed.

143.—*What practical point commends itself from this danger?*

Having regard to the cases in which gases from the soil (from leaking gas pipes, sewers, etc.) find their way into water pipes, it would seem important not to lay water pipes near any other pipes, or what is better, have all gas pipes in sub-ways, where they can be inspected.

CHAPTER II.

WELL WATERS.

144.—*What are the different varieties of wells?*

There are three varieties of wells, *shallow* or *superficial, deep,* and *artesian.* [The waters of these wells vary much in quality. The last mentioned may be considered a variety of deep wells.]

145.—*What is a deep well?*

A *deep well* is one that passes through the first impermeable stratum of the soil, which stratum sometimes consists of stiff clay but often of rock. The ordinary depth of such a well is from 40 to 50 feet. Sometimes however, these wells have a much greater depth. In other words deep wells are those which are sunk to considerable depths through regular geological strata, such as chalk, oolite, and sandstone in search of water. Those also are known as deep wells which pass through a superficial porous bed and an underlying impermeable stratum to reach water-bearing strata at greater depths, though often at no great distance from the surface. Thus it may happen that a shallow well sunk 50 feet into a porous soil may be deeper than a deep well at no great distance away, which passes through the impermeable stratum upholding the water which supplies the shallow well.

146.—*What are shallow wells?*

Shallow wells are those which are sunk merely into the superficial stratum of porous soil. It is not easy to draw any particular line as to depth, but generally wells less than 30 feet deep must be reckoned in this class, unless there should be an impervious stratum passed through which shall effectually shut out surface-waters. A *shallow* well is one that is of meagre depth, sunk only to the extent of 20 to 30 feet; or, if deeper than this, one that does not extend below the surface through the first impermeable stratum of the earth's crust. "Shallow" wells may really be deeper than some "deep" wells. Thus, a well 15 or 20 feet deep, passing through a stiff clay before it reaches the water-bearing stratum, is really better than one of twice the depth which penetrates a superficial porous stratum only. They are usually sunk into superficial porous beds of sand or gravel overlying an impermeable stratum of clay or dense rock. Superficial wells sometimes receive the subsoil drainage water from swamps, cesspools, grave-yards, vaults, etc., rendering the water unfit for use. Such water is therefore exposed to pollution owing to the presence of the many impurities contained in the surface layer of the soil. [Water from such wells is almost always unwholesome, and of very suspicious quality. It should never be used for drinking purposes without previous purification by filtration or preferably by boiling and filtration. The distinction between the two (deep and shallow wells) is not very clearly defined, but it may be considered generally to depend more on their nature than their depth; shallow wells being those which are sunk into a superficial bed of drift sand or gravel resting on an impervious stratum, and deep wells those which are sunk into the regular geological formation, such as chalk, greensand, sandstone, etc. In fact, the distinction between shallow wells and deep wells is very much the same as that between land springs and main springs.] Generally speaking, our rule should be to go deep enough to place an impervious stratum between our water-supply and the surface of the ground. If we cannot do this, we must go as deep into our water-bearing stratum as possible, both because the supply will be more plentiful, and because the water itself will have a better chance of being purified by its longer passage through the soil before it reaches the level of the well. (See No. 249.)

147.—*What are the characters of deep well water?*

The water of deep wells owes its character to the rock formations through which it has passed, upon which also depend its mineral constituents. As a rule, it is pure and free from contamination from organic matter, even when sunk in the midst of inhabited localities if the well has been properly constructed. They may however contain nitrogen as nitrites and nitrates. The quality of deep well water varies, therefore, in accordance with the nature of the geological formations through which the water flows before entering the well. The solubility of the component elements of these strata by water charged with CO_2 markedly influences the quality of the water. Local experience is generally sufficient to indicate what the quality of the water ought to be. Deep well water is much harder than river water. The hardness is chiefly due to lime salts, especially the carbonate, held in solution by excess of carbonic acid. The water is usually cooler, and contains less organic matter than superficial wells, and even if subsoil water does find its way to it, that water has to pass through a greater depth of earth, with the result that almost all the organic matter is removed by natural filtration.

148.—*Illustrate by an example the labour expended in the supplying of a household with well water?*

Suppose that a family of six persons are supplied with 12 gallons each per diem, then 72 gallons has to be daily conveyed to the house. Say the average distance of the well is 50 yards (many are 200 or 300 yards off) and the depth of the well 30 feet. One gallon of water weighs 10 lbs.; 72 gallons, 720 lbs., which raised 30 feet = 21,600 lbs. The same carried 50 yards or 150 feet = 108,000 lbs., or about 48 foot tons, in all there being about 60 foot tons of labour expended. Modern public waterworks aim at altering this by providing water at the doors of the inhabitants.

149.—*Upon what does the possibility of obtaining a good and wholesome supply from wells depend?*

Generally speaking, the chance of obtaining a good supply will depend upon the nature of the underlying strata, upon the level, and upon the site. Wells sunk in superficial sands or gravel beds, though yielding a good supply at ordinary times, are very liable to have their yield very much lessened in seasons of drought, unless they are situated at points considerably below the level of the surrounding country, and the same remark applies to wells in the chalk districts. On the other hand, wells or borings in the new red sandstone and limestone formations usually yield a large and constant supply, because these permeable rocks are so saturated with water that they may be regarded as vast subterranean reservoirs.

150.—*Are deep wells open to this objection?*

No, because they are generally sunk through an impervious stratum, which prevents the infiltration of any surface impurities, and at the same time serves to keep down the water in the porous strata beneath these wells. The quality of the water will depend upon the nature of the geological formation of the locality. It is also apparent that, in accordance with a well-known physical law, it is only necessary to bore through the impervious stratum and reach the water-bearing bed for the water to rise to the surface, or to within a short distance of it, so as to be collected in a well of ordinary dimensions. Indeed, in certain low-lying districts, where a boring is made at a point considerably below the level of the line of infiltration into the water-bearing stratum, the water rises above the surface and overflows. Such overflowing wells—or artesian wells, as they are called—were once common in the Valley of the Thames, and are still to be met with in the flat lands of Essex and in Lincolnshire.

151.—*State briefly the general characters of waters from (a) Springs, (b) Superficial wells, (c) Deep wells, (d) Artesian wells?*

(*a*) Always much harder than lake or river water, and, as a rule, wholesome and palatable.

(*b*) Superficial wells are apt to contain organic matter from churchyards, cesspools, etc., and also salts, sulphates, and carbonates of lime—the latter kept in solution by excess of carbonic acid. By an improved system of sub-soil drainage, the waters from these wells may be rendered pure and wholesome.

(*c*) Deep wells contain much lime, and are, as a rule, wholesome and palatable. Water from wells which are dug deep into the ground, or into rock, such as chalk or sandstone, is equal in quality to spring water

(*d*) Artesian wells may contain large quantities of the alkaline carbonates and sulphate of lime, but as a rule they are wholesome and palatable though less aerated than the others.

152.—*Which is the better for domestic purposes, spring and deep well water, or upland surface water ?*

Upon this point the Rivers Pollution Commissioners stated "that preference should always be given to spring and deep well water for purely domestic purposes, over even upland surface water, not only on account of the much greater intrinsic chemical purity and palatability of these waters, but also because their physical qualities render them peculiarly valuable for domestic supply. They are almost invariably clear, colourless, transparent, and brilliant—qualities which add greatly to their acceptability as beverages; whilst their uniformity of temperature throughout the year renders them cool and refreshing in summer and prevents them from freezing readily in winter. Such waters are of inestimable value to communities, and their conversion and utilisation are worthy of the greatest efforts of those who have the public health under their charge."

153.—*If wells are to be used, what points should be observed ?*

Special attention should be directly given to the quality of the water; and any deep ash-pits, midden-privies, or cesspools near wells should be removed and the drains examined. If the water is pumped up by means of a force pump into a cistern, for the purpose of supplying the closets, it will generally be found that the cistern also supplies the housemaid's sink.

154.—*What has been found in regard to stored well water ?*

With reference to the storage of deep well water, it has been found in many cases that there is great liability of vegetable growth to occur when the water is exposed to air and sunlight, so that, if it becomes necessary to store the water before distribution, covered reservoirs must be used for the purpose, at least, in warm climates.

155 —*Where are deep wells sunk ?*

Deep wells are sunk through impervious strata into pervious strata, the water in the latter being confined by the impervious bed.

156.—*Whether is spring and deep well water, or surface and river water, best for domestic supply ?*

In all cases in which spring and deep well water of good quality are available, we recommend that they should be employed in preference to surface and river water for domestic supply.

157—*What special points demand attention in the sinking of shallow wells?*

The yield of shallow wells varies according to season, therefore the well must be deep enough to reach the level of the water in times of drought. Such a well drains a wide area, and is liable to be polluted by any impurity of the soil within a considerable radius of its mouth, and as the supply is at best subsoil water, due regard must be had to the possibility of pollution at comparatively distant points. It should be lined with brick and puddled, and the brick lining should be brought a foot or two above the ground so as to exclude surface washings by forming a coping. If the soil is polluted, or if the water found is impure or insufficient in quantity, the boring should be carried through the first impervious stratum to other water-bearing strata deeper down. Sometimes the water in the deeper strata is under sufficient pressure to make it rise to the surface and overflow, forming an "artesian well" or artificial spring. The flow in dense strata being slow, each well exhausts a considerable area, and the yield of water cannot be greatly increased by multiple borings. Borings in sandstone or limestone give large and constant supplies, owing to the enormous accumulations of water they contain, but wells in superficial sand or gravel beds, or chalk, often fail in dry seasons.*

158.—*What are the varieties of wells, as regards method of using the waters thereof?*

There are three kinds:—(1) pump-wells, (2) draw-wells, and (3) dipping-wells.

159.—*A draw-well is sometimes liable to contamination; explain how this pollution occurs.*

The cover is necessarily removeable, and is usually on the same level as the surface of the ground. The cover is often left open, and small animals, such as dogs, cats, and rats, sometimes fall in; and, the occurrence being unknown, the animals decay there and contaminate the water, the cause of the consequent illness of the persons who drink the water being probably undiscovered.

160.—*Should dipping-wells be used?*

They should not; a dipping-well, the water of which is used for domestic purposes, ought not to be allowed to exist.

161.—*In what ways may dipping-wells be contaminated?*

Dipping-wells are subject to contamination from many sources. The cans, buckets, and pails used are set down in dirty places about the house, and the dirt is carried to the well and washed off in the act of dipping. Also, every time anything is dipped into the water, the water is stirred up and muddied for the next person who comes. Another source of pollution of an open well-hole is the mischief of children, and where the situation is public, this cannot be prevented. These dipping-wells are weak springs, and as the overflow of water may probably be frequent, a cattle-trough may be so placed as to receive the overflow; in public places this is of great use.

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* WHITELEGGE's *Hygiene and Public Health.*

162.—*Should the openings of the mouth of a well be always closed?*

Every opening should be completely closed, except one for ventilation, which should be protected by a hood, so that it cannot be reached, and another for the overflow of water, which should likewise be shielded, the water being drawn by means of a pump.

163.—*Are free N_3 and chlorides in deep well water always indicative of dangerous impurity?*

Deep wells often show a large amount of free ammonia and chlorides without necessarily indicating pollution; but the same amounts in a shallow well would point to probable sewage pollution, or at least to the presence of urine.

164.—*From what strata are the largest supplies of deep well water obtained?*

In England they are obtained from the chalk, oolite, and new red sandstone strata.

165.—*Upon what does the nature and amount of mineral matter in springs and wells depend?*

They are determined by the soluble constituents of the various strata through which the water has passed, and the organic impurities are regulated by the facilities for pollution in the superficial soil and the completeness of purification by filtration lower down. Hence the water in shallow wells, especially if situated near dwellings or manured lands, is liable to contain much organic matter washed from the soil, with or without partial oxidation into nitrates or nitrites; and also chlorides which usually accompany organic impurities of sewage origin.

166.—*What is the extent of ground drained by a well?*

A well drains an extent of ground about it in the shape of an inverted cone. The area must depend on the soil; but the experiments at Grenelle and Passy show that the radius of the area drained is equal to four times the depth at least,* and that it often exceeds this. Professor Ansted states that the deepest (non-Artesian) well will not drain a cone which is more than half a mile in radius. The distance through which the hollow inverted cone will extend or make itself felt will vary according to the greater or less porosity of the soil, and may extend to from 15 to 160 times the depth of the cone. More recent investigation has shown that the surface of the underground water in the area of the circle drained by a well depressed by pumping, has the form of a curve, analogous to the natural curve of the underground water, with steep vertical gradient near the well, but rapidly becoming more nearly horizontal as the distance from the well increases. This distance—the radius of the circle drained by the well—is best expressed in terms of the depression. In fine sands and gravels, which offer considerable resistance to the passage of water, the distance varies from 15 to 39 times the depression. When, however, the amount of water abstracted is sufficiently great to cause a considerable depression of the water in the well, the conditions are altered; for the well then drains an area all around it in the form of a circle, that is to say, the water in the well is renewed not only from above—as regards the flow of underground water—but from below; and in such a case it would not matter what position the well had to the cesspool, if the cesspool was included in the area drained by the well, for pollution must inevitably occur. The distance within which a well draws water to itself, when its own water level has been depressed by pumping, depends on the amount of the depression and on the nature of the soil.

167.—*Explain the method by which pumping increases the liability to pollution?*

If the level of the water in a shallow well be reduced by pumping, say 2 feet, water will be aspirated into the well from a distance of 15 × 2 = 30 feet as a minimum, to 160 × 2 = 320 feet as a maximum. The set or current of the underground water in the neighbourhood of a pumped well must, indeed, always be towards the well; and it is by the suction exerted on cesspools situated in proximity to wells that they are emptied when these are pumped.

A shallow or surface well sunk into the porous soil will draw no water until it reaches the stratum of underground water. Into this the liquid soaking from leaky sewers, drains, and cesspits will find its way more readily than the surface water.

168.—*At what depth will water be reached in a clay basin?*

If the surface of the clay basin is very irregular, as is commonly the case, it is impossible to predict at what depth the water will be reached or at what level it will permanently stand.

Theoretically, it may be inferred that the superincumbent stratum of sand or gravel is situated below the level of the lowest point at which the water can escape from the clay basin.

169.—*How may the yield of wells be ascertained?*

The yields of wells can only be known by pumping out the water to a certain level and noticing the length of time required for re-filling to the original level—the superficial area of the transverse section of the wells having been previously ascertained. In cases of copious flow of water a steam-engine is necessary to make any impression; but, in other cases, pumping by hand or horse labour may be sufficient perceptibly to depress the water, and then, if the quantity taken out be measured, and the time taken for re-filling the well be noted, an approximate estimate can be formed of the yield.

170.—*What is the effect of pumping water from wells?*

The pumping of water from the well causes the lowering of the natural water level, and if the pumping be regulated so as to keep the level of the water in the well at a certain fixed point, the ground-water in the neighbourhood of the well also assumes a constant level. The influence of the pumping will be felt in all directions. The distance to which the measurable influence of the pumping is felt, in any case, depends, other things being equal, upon the character of the water-bearing deposit The more a well is pumped the greater its liability to contamination from neighbouring sources of pollution.

171.—*How is the subsoil water related to a well?*

Around a well, the surface of the ground-water in the soil will be found to take the form of a hollow inverted cone, with its apex at the level of the water, in the well, the base of the cone merging imperceptibly in the general level of the adjacent ground-water.

172.—*What is the direction of the movement of the underground water?*

Generally in the direction of the sea, or the nearest water-course.

173.—*What is the depth of the underground water?*

It varies from 2 or 3 feet to several hundreds.

174.—*How does pumping water from a well affect the position of the subsoil water in relation to the water?*

When the well is pumped, the apex of the cone will be depressed, and the area of its base will be extended—the cone becoming flattened out as it were.

175.—*What effect has this on the drainage area of the well?*

The drainage area of the well will thus be increased, and if there be any cesspool, pervious sewer, or leaky drain within the area of the cone, the polluting liquids will be drawn into the well by suction. Hence, the great danger attendant on the use of shallow wells, and all wells sunk into pervious soils only. When much water is removed from a superficial well, the level of the water in it descends below that of the subsoil or ground water.

The subsoil water now directly feeds the well and flows towards it in such a way, that the area of soil draining its water into the well forms a sort of pyramid with the apex downwards, the apex corresponding in size with the calibre of the well itself. The result is that all the soil that is embraced in the area covered by the base of the pyramid drains its water into the well. Further, the impurities of any foul ponds, and filth deposits within its reach, are washed into the well. In the case of some wells the larger the quantity of water drawn from them the larger the base of the drained area, the greater the amount of subsoil water drained into the well. [The area of soil drained by a well, roughly corresponds to a circle, the centre of which is the well itself, and the radii from four to eight up to 160 times the depth of the well. In some cases, however, the area drained is considerably greater than this, the diameter of the drained area being 200 yards or more. It will thus be seen that no source of pollution should be permitted to exist within 100 feet of a well, and even this distance is, in many cases, insufficient to prevent contamination. For a well to afford a permanently wholesome water, it must be sunk below the first impermeable geological stratum, and be fed by the subterranean lake that exists there. This deep supply is rarely reached at a depth less than 50 feet. The area of surface drained by wells is not a question without its difficulties. It has been stated as a circle, the radius of which is several times the depth of the well; but this appears to be a grave under-statement of the case, if we look to the evidence which has been obtained from the effects of pumping upon distant wells, or the way in which wells have sometimes been drained by outflows of water at distant lower levels. On these points one or two remarks may here be made. A well in a gravel and sandy soil in South Hampshire was found to be drained dry in consequence of an outflow of water in a gravel-pit dug a considerable distance off. The difference of level between the higher point (that is, the bottom of the well) and the lower (the outflow at the gravel-pit) was 21½ feet—the distance between the two, 1,720 feet; so that the area drained had a radius equal to 80 times the depth, here represented by the fall or difference in level between the two points. In this case the loss of water was obviated by deepening the well about 10 feet.]

176.—*How does the taking of water from the underground supply resemble the taking of water from a pond or lake?*

Suppose that we have a lake or pond, generally situated in a valley, with no considerable visible inlet, and yet from which experience has shown that a certain number of gallons daily can be withdrawn without affecting its level; if this lake be now filled with sand and gravel, we can still pump the same daily quantum (even more, owing to lessened evaporation); but, owing to the resistance of the material, the level of the water does not equalize itself at once, although, if the pumping cease, the water in the well soon rises to the normal level of the ground water.

177.—*Give the results of the analyses of shallow wells by the Rivers Pollution Commissioners?*[*]

In 1868 they analysed a large number of waters from shallow wells with the following results:—

1. Waters from shallow wells in or upon Silurian Rocks and Gneiss.—Solids 2·4 to 70·1 grains per gallon; average 16·7 grains. Hardness 2°·4 to 29°·1; average 7°·5.

2. Waters from shallow wells in Devonian Rocks.—Solids 8·5 to 73·6 grains; average 27·5 grains. Hardness 3°·5 to 39°; average 14°·6.

3. Waters from shallow wells on the Yoredale and Millstone Grits.—Solids 4·1 to 93·5 grains per gallon; average 35·1 grains. Hardness 2° to 63°; average 22°·1.

4. Water from shallow wells in the Coal measures:—Solids 6·6 to 154·6 grains per gallon; average 48 grains. Hardness 2°·4 to 98°·6; average 24°·4.

5. Waters from shallow wells in or on Mountains Limestone and Magnesian Limestone.—Solids 32·1 to 76·2 grains per gallon; average 50·4 grains. Hardness 28°·5 to 62°; average 40°·9.

6. Water from shallow wells in or on New Red Sandstone.—Solids 14·4 to 168·1 grains per gallon; average 71·1 grains. Hardness 12° to 89°; average 34°·5.

7. Water from shallow wells in or upon the Lias.—Solids 26 to 214°·8. Hardness 1°·9 to 81°·8, average 35°·8.

8. Waters from shallow wells in or on the Oolite.—Solids 21·7 to 188·7 grains per gallon; average 64 grains. Hardness 16°·1 to 55°·2; average 32°·4.

9. Waters from shallow wells in or on the Upper and Lower Greensand and Wealden Beds.—Solids 7·4 to 266·8 grains; average 50 grains. Hardness 2°·7 to 56°·4, average 19°·7.

10. Waters from shallow wells in or on the Chalk—Solids 22·7 to 111·4 grains per gallon; average 55·6 grains. Hardness 16°·7 to 50°; average 30°·5.

11. Waters from shallow wells in Gravel on the London Clay.—Solids 22·3 to 277·5 grains per gallon; average 71·2 grains. Hardness 10° to 133°·7; average 35°·6.

12. Waters from shallow wells in Bagshat Beds.—Solids 16·2 to 200·8 grains per gallon; average 82·2 grains. Hardness 9°·2 to 92°·2; average 38°·5.

13. Water from shallow wells in Fluvio—Marine Series.—Solids 5·7 to 46·3 grains per gallon; average 19·1 grains. Hardness 3°·2 to 25°·5; average 10°·8.

14. Waters from shallow wells in Alluvium and Gravel.—Solids 20 to 224·5 grains per gallon; average 69·6 grains. Hardness 3°·2 to 106°·7; average 33°·3.

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[*] First Report of the Rivers Pollution Commissioners, 1868.

178.—*Do all shallow wells get their supply from the ground water?*

They do not; there are certain shallow wells which do not draw their supply from the ground water, properly speaking, but are sunk so as to intercept the water flowing through a rocky fissure, or are sunk into the rock so as to form a collecting basin or reservoir. Such wells are in some respects even more liable to contamination than the wells sunk into the ground work, for, in the pores or interstices of a gravelly soil, there is a continually changing body of air which affords more or less opportunity for the oxidation of the organic matters, so that the process of rendering the well unfit for use is a gradual one; and often a well will furnish good water for a long time and then become suddenly bad—suddenly, it seems to those who have not been aware of the progress of the pollution. On the other hand, a well which is sunk into the rock may receive from a considerable distance sewage-matter which has found its way almost directly into the well along the surface of the rock, or through some fissure.

179.—*What is the chief objection to shallow wells as a source of drinking water?*

The main objection is on account of their liability to contamination from surface drainage and subsoil impurities.

180.—*Name another disadvantage of surface wells?*

Surface wells often dry up in summer time owing to their being dependent on the subsoil for their water supply.

181.—*When sewage is discharged in excessive quantities on the surface of a porous soil, what becomes of it?*

It quickly percolates through this until it meets with an impervious stratum which arrests its downward course.

182.—*Can you mention any specific instance of epidemic disease that was traced to the effects of pumping water from wells?*

Some years ago the town of Croydon in Surrey was visited by an epidemic of typhoid fever, which was traced to the water derived from deep wells. Mr. Baldwin Latham made observations which showed that when the pumps were worked, the level of the ground water was lowered, and sewage was sucked out of the sewers, passing, as he alleged, into the wells supplying Croydon.

183.—*Does change in the level of the subsoil water affect the purity of well water?*

It does; Sir George Buchanan has pointed out that the purity of water in wells is liable to be affected by changes in the level of the ground water, and the readiness with which enteric fever is spread by means of specifically polluted water in this way has been proved and should not be lost sight of.

184.—*Does a shallow well water act on lead?*

It does so most actively; polluted shallow well waters have been known to have a very powerful and persistent solvent action on lead, probably from their containing excess of carbonic acid, which tends to dissolve the coating of carbonate of lead formed in the pipe or cistern. The chlorides, nitrates and nitrites in such water have likewise powerful plumbo-solvent properties.

185.—*On the whole then should shallow wells be used as sources of supply?*

They should not; shallow wells should, if possible, be avoided as sources of water-supply. They are very prone to be contaminated with organic filth, derived from the soakage of sewage and slop-water into a porous soil.

186.—*From its origin what may be said of shallow well waters?*

That the water of shallow wells is exceedingly liable to contract impurities, through surface drainage passing into them. Matters derived from soils, vegetable and animal products, often contaminate such waters and when shallow wells are situated near human habitations, there is more than ordinary risk of serious pollution from sewage matters taking place.

187.—*What is the cause of the difference in the depth of surface wells given by different authorities?*

Some authorities place the depth of surface wells at 15 to 30 or even more feet. It may be more correct to state that surface wells get their supply from the subsoil water or above the first impermeable layer of the earth's crust.

188.—*Are not surface wells and cesspools sometimes constructed adjacent to one another?*

They frequently are; commonly one hole is dug in the garden for a well, and another for a cesspool, while there is possibly a farmyard near at hand—the soakage from the cesspool and farmyard being direct into the well. In fact, the sinking of a pump-well into the same stratum as contains a cesspool is like using the same river as a carrier of sewage and a source of water-supply. The intimate connection between wells sunk into the same water-bearing stratum is readily proved; for, by the opening of new wells, there is often effected a very considerable diminution of the supply furnished by the older wells.

189.—*Under what exceptional circumstances may a surface well be used?*

If a surface well is ever to be constructed and used, it should be in a field or open space, remote from habitations and their surroundings, and in a place where soakage from cesspools is impossible, and when no other source of supply is reasonably accessible.

190.—*What are the chief forms of impurities in shallow well waters?*

Surface or shallow well waters, though sometimes comparatively pure, frequently contain a large amount of organic matter derived from draining the organic and mineral matters around houses. The water in them frequently becomes contaminated by foul matters from leaky sewers, cesspools, etc., especially in porous soils

191.—*Through what are most surface wells sunk?*

Most surface wells are sunk into a bed of sand or gravel resting upon an impermeable stratum of clay.

192.—*Where are wells suitable as sources of supply?*

In large isolated buildings, such as lunatic asylums, workhouses, prisons and isolated mansions, they usually supply the whole of the water required. In selecting a site in the country for any such building, the possibility of obtaining the requisite supply, and the cost at which it can be produced, are points of the first importance.

193.—*Are wells always reliable for this purpose?*

By no means. If a deep well is properly steined, and the joints and lining impermeable, the subsoil water level may be much higher than the lower limit of the steining, and though the water will be forced into the well above this lower limit of the steining, the pressure will, as a rule, fall short of causing it to reach the exact height of the subsoil water level; and in the case of a deep well sunk through rock, or a bed of clay, no subsoil water reaches the well at all if it is properly steined.

194.—*What kinds of pumps are in use?*

There are two kinds of pumps in use—the ordinary *suction pump* and the *forcing pump*. The former will answer the purpose so long as the distance the water has to be raised does not exceed from 30 to 33 feet; in fact, as a rule, taking imperfection of mechanism into account, 25 feet may be looked upon as the limit. In the case of deeper wells it is necessary to fix the more elaborate and expensive forcing pumps; hence it is that in practice one so often finds open wells with a bucket and windlass for raising water.

195.—*What may be said against the use of the bucket and windlass?*

With these the danger of surface of pollution is increased, and if the arrangement be allowed to continue, as in the case of small cottages probably it will, the greatest care must be taken to see that the top of the well is so situated with regard to the surface as not to permit of drainage into it. A good fitting cover ought to be insisted upon, otherwise dead leaves and other decaying matter will find their way into the well.*

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*For a full and simple description of the Construction of Pumps see *Well-Sinking*, WEALE's Rudimentary Series.

196.—*What is the theory of the use of the pump for raising well water?*

The pressure or gravity of the atmosphere being equal to a column of water 34 feet in height, is the means or principle on which rests the utility of the common pump, also of the syphon, and all other such hydraulic applications. In a pump the internal pressure on the surface of the liquid is removed by the action of the bucket, and as by degrees the density becomes lessened, so the water rises by the external pressure to the above-named height; and at such height it will remain, unless by some derangement of construction taking place, the atmospheric fluid is allowed to enter and displace the liquid column. But if the temperature of the water or the liquid be so elevated that steam or vapour arises from it, then the action of the pump will be wholly or partially destroyed according to the density of the vapour, and the only way to proceed in such cases is to place the working bucket beneath the surface of the liquid which is required to be raised.

197.—*How should the pump be placed in the well?*

The pump should be wholly enclosed within the well, and a horizontal shaft or spindle should traverse the well from wall to wall, carrying upon it an arm to work the pump-bucket, having only its end projecting through the wall, upon which is fitted a simple lever or handle 18 inches or so in length. Being wholly enclosed or bricked up, the pump barrel should be lined with brass or gun metal, well and truly fitted in every respect, so as to prevent the need of frequent repairs, which is a too common need of many pumps.

198.—*How are wells used as filth reservoirs?*

Suppose we have a well in which the water rises just to the surface of the ground, but does not overflow, and that if 100 gallons per minute be pumped regularly, the water-level is lowered a distance of five feet; the same well may be made to absorb 100 gallons per minute by extending the tubing five feet above the normal water level. When the natural level of the water is much below the surface of the ground, an enormous amount of liquid may be disposed of for an indefinite time, provided the refuse be not of such a nature as to clog the pores of the absorbing stratum into which the liquid finds its way, or provided the well is frequently cleaned. There is a well of this kind at Bondy, near Paris, which is 74 metres in depth. Such a method of disposing of refuse should not be allowed, unless it is absolutely certain that the stratum into which the water finds its way carries naturally water which is totally unfit for use, and which will never be called upon for water-supply, and unless, further, there is security that the well does not pass through strata which contain water fit for use. It is well known that it is very difficult to prevent the leakage of the water which rises in artesian wells into the upper strata, and this leakage often causes a very considerable diminution of the amount of water which would otherwise reach the surface.

199.—*What subsoil formations give sparkle to water and improve its quality?*

Chalk formations, oolites, greensand, and new red sandstone.

200.—*Upon what does the depth of a deep well depend?*

The depth of the well must, of course, vary with the vertical distance of the impermeable stratum from the surface of the earth; as a rule, this distance is not great, and in fact it is often said that shallow wells are those which are less than fifty feet deep and deep wells those that are greater than 50 feet in depth; but it is better to keep to the definition here given.

201.—*What precautions should be observed in making a surface well?*

They are as follow:—In the first place, the spot selected for a surface well ought to be as far removed from all sources of pollution as possible, and in the opposite direction to the natural fall, so as to tap the water previous to its reaching the polluting source, and not after it has travelled past it. The importance of this will be understood from the description already given of the course that the subsoil water takes. In addition to this, the lining of the well must be so constructed as to be quite impervious to soakage from the surface immediately surrounding it.

In place of the brick work or masonry being loosely laid around it, which is the usual practice, it ought to be set in cement down to the water level, and as an additional precaution, it is well to interpose a layer of puddled clay all round, between the brick work and the adjoining soil. Every well ought to be provided with a pump, and be covered over by means of stone slabs, carefully adjusted and sealed with cement. By reason of such precautions, is that in place of entering the well direct, all surface water must percolate through the intervening stratum, and, in doing so, become more or less purified.

202.—*Is the quality of cement used in well-making of importance?*

It is; the quality of cement used is very important, the best' Portland cement being alone admissible for this, as for all sanitary work. The proportions of added sand ought, for this particular purpose, to be two of sand to one of cement, and the sand and cement ought to be thoroughly well mixed before the water is added. The sand selected must be clean and fine, and quite free from any dirt or clay, otherwise the cement will not set. Builders and workmen require careful watching as regards these points.

203.—*If pollution of well water is suspected, what course should be adopted?*

In all cases in which well pollution is suspected, it is advisable to open the well in order to ascertain whether there is any evidence of the penetration of sewage matter above the water level. If such be the case at one point or another, the brickwork, in place of presenting a clean, red surface, will be discoloured in a manner which, when once seen, will never be mistaken. Apart from this it is highly desirable that wells should be *opened periodically* for the purpose of being cleansed, as, however well constructed they may be with lime, impurity may arise.

204.—*If steining wells with bricks, how are they laid and jointed?*

In steining wells the bricks are laid flat, and are arranged to break-joint. In 9-inch work they are laid all as headers; and in 14-inch work there is generally an inner ring of the usual 9-inch work, all headers, and an outer ring of 4½-inch work, all stretchers. In wells up to 9 feet in diameter, 9-inch work is generally sufficient, and 14-inch work may be adopted up to 14 feet diameter. If the ground is bad or loose a half-brick extra should be added.

205.—*What conditions are absolutely necessary to make wells safe as sources of supply?*

Wells can never be considered safe, unless they are sunk through an impervious bed of soil into a porous stratum beneath, and are well cemented down to the clayey stratum. For precisely the same reasons as are stated above, it is equally necessary, in the case of deep wells, to protect the surface by carrying the impervious brickwork down as far as the impervious stratum.

[Wells which do not conform to this rule are too abundant in most rural districts, and are fertile sources of mischief.]

206.—*Is water always found beneath the first impervious stratum?*

It is not infrequently found, that when the impervious stratum is penetrated, the water, previously abundant, is lost; and then the only plan is to carry the well downwards till at a greater depth water is again found.

207.—*What precautions ought to be taken in obtaining water-supply from wells in proximity to dwellings?*

That the well should be sunk to such a depth as to reach a water-bearing strata. Its construction should be the most perfect, thoroughly impervious to external or internal percolation. The greatest care should be exercised in seeing that all drains are properly constructed, and if in near proximity, bedded in cement concrete. All possible sources of contamination, such as dung-heaps, earth-closets, privies, ash-pits, etc., should be dealt with as laid down in the new Model Bye-laws of the Local Government Board, and the rainfall and surface water generally, carried off, so that by no possible means could it find its way into the well.

208.—*What is the reason that ignorant people do not often construct deep wells?*

Because abundance of water is often reached before the first impervious stratum of soil is penetrated, and at a small depth—they tap the subsoil water.

209.—*How are shallow wells usually brought into existence?*

"In the little yard or garden attached to each tenement, or pair of tenements, two holes are dug in the porous soil; into one of these, usually the shallower of the two, all the filthy liquids of the house are discharged; from the other, which is sunk below the water line of the porous stratum, the water for drinking and other domestic purposes is pumped. The two holes are not unfrequently within 12 feet of each other, and sometimes even closer. The contents of the filth hole, or cesspool, gradually soak away through the surrounding soil, and mingle with water below. As the contents of the water hole, or well, are pumped out, they are immediately replenished from the surrounding disgusting mixture, and it is not, therefore, very surprising to be assured that such a well does not become dry even in summer. Unfortunately, excrementitious liquids, especially after they have soaked through a few feet of porous soil, do not impair the palatability of the water; and this polluted liquid is consumed from year to year, without a suspicion of its character, until the cesspool and well receive infected sewage, and then an outbreak of epidemic disease compels attention to the polluted water. Indeed, our acquaintance with a very large proportion of this class of potable waters has been made in consequence of the occurrence of severe attack of typhoid fever amongst the persons using them."

210.—*How may wells in villages become polluted?*

From sewers, drains, dung-heaps, ash-pits, water-closets, privies, or other accumulation of noxious refuse or liquids being in too close proximity to the wells. In villages wells are frequently placed in the garden, and the annual manuring has been found to be the cause of pollution. The water may be perfectly clear to the sight, but contain a large percentage of nitrates or filtered sewage, causing enteric fever, diarrhœa, etc. Other sources of pollution are—proximity to graveyards, byres, stables and houses.

211.—*In general terms state how pollution of wells may be prevented.*

To prevent pollution, wells should be placed clear of all buildings, out-houses, drains, cesspools, etc., they should be of sufficient depth, and lined inside with cement to a depth of at least 30 feet.

212.—*Enumerate the general sources of contamination of well water.*

(1), Privy cesspools which are not water-tight and from which rain-water is not excluded; (2), soakage of the tap-water into the ground and thence into the wells, conveying with it refuse matter from the surface; (3), house-drains which lie near the well, and which allow the house slops to percolate through the joints into the surrounding ground, from which they gradually soak into the well; and (4), unless the drain consists of pipes closely jointed, rats are a frequent cause of contamination of wells near which house-drains lie, for rats seem to have a peculiar instinct in finding their way through the ground direct to water, and, although the water in the well may be out of their reach, it is possible that in their efforts to reach it some of them drop in; but, even if that should not be so, refuse liquids may find their way through the holes they make from the drain to the well.

213.—*When shallow wells are sunk into an alluvial, gravelly soil, in the immediate proximity of a river, how may they be polluted?*

They may become contaminated with filth carried laterally to great distances, owing to the 'set' of the ground-water in a particular direction, generally towards the bed of a river or nearest outfall. Such underground streams are by no means uncommon, and, when pure, form uniform and excellent supplies, such as those which have furnished water to Dresden.

214.—*Do the characters of well waters vary?*

They do very considerably. Thus the water from deep wells and springs varies according to the geological strata through which it passes. Alluvial waters are more or less impure containing a large amount of salts (20 to 120 grains per gallon) and often much organic matter; while chalk waters are clear, wholesome, and sparkling, holding in solution a considerable amount of calcium carbonate besides other salts, and are largely impregnated with carbonic acid; they are also wholesome and agreeable to the taste, but not very suitable for cooking purposes.

215.—*Are wells important as sources of supply?*

They are; in 1876 it was said twelve millions of the country population derived their water almost exclusively from shallow wells, and these are, so far as our experience extends, almost always horribly polluted by sewage and by the animal matters of the most disgusting origin. The common practice in villages, and even in many small towns, is to dispose of the sewage and provide for the water supply of each cottage, or pair of cottages, upon the same premises.

216.—*What is the essential origin of deep wells?*

Deep wells are derived from subterranean springs.

217.—*What then is the essential condition necessary for the construction of deep wells to yield a good supply?*

That they be sunk through impervious strata into pervious strata, the water in the latter being confined by impervious strata. [Superficial wells tap the underground water held up by the impermeable stratum, and yield a water identical in composition with that flowing from the " land " springs in the neighbourhood]

218.—*What then is the only real protection in the construction of a well?*

To sink the well through the first impervious layer of soil, and to cement the sides throughout to a point below the impervious stratum, so as to draw water from the deeper strata, and to protect this water from the more superficial polluted surface water.

219.—*Is the source of deep well water on the confines of the well itself?*

By no means; the water which supplies deep wells has usually travelled a comparatively long distance since it fell as rain on the surface of the earth. The outcrop of the water-bearing strata on the surface may be many miles from the spot at which the well is sunk, as is the case with the deep wells in the chalk stratum sunk through the London basin.

220.—*Why are wells more expensive than springs?*

Because the water has mostly to be raised by human, animal or steam power. Artesian wells, so-called, are artificial springs which although initially very expensive in their construction are ultimately moreec onomical and yield hygienically unobjectionable water.

221.—*Supposing the original source of deep well water to be pure and wholesome; how may it be kept so in the well itself?*

By properly steining the sides of the well with brickwork set in cement as far down as the first impermeable stratum; by this means surface water and underground water resting on this stratum are entirely excluded, and the well is freed from those sources of pollution which so greatly contaminate shallow well waters. Steining should also be applied to deep wells sunk through porous strata for the *whole* of their depth; in this way surface pollutions are compelled to pass through considerable thicknesses of soil before reaching the well and are therefore well filtered.

222.—*What is the original source of the water of wells and springs?*

The water of all wells and springs is derived from rain. The rain-water percolates through various surface soils until stopped by an impermeable stratum of clay or a layer of rock. In the impermeable strata the water collects, rendering them water-logged up to a certain level, the line of this water-logging corresponding with the lowest level of the natural outlet through which the subterranean water is escaping to rivers, streams, etc. Beneath the soil, then, we have an extensive subterranean reservoir, and it is this reservoir that is tapped when a deep well is sunk through stiff clay or rock. The source of the water in deep wells is thus the same as that of springs, and the composition of the water in wells will be very much the same as that of the spring-water derived from the same strata.

223.—*How is the relation between the supply of shallow wells, disease, and low ground-water, explained?*

Some explain it by stating that it is due to the greater concentration of the impurities in consequence of decreased supply; that there is decreased fluctuation when the ground-water is low, and this decreased motion of water is associated with stagnation, and stagnation with deterioration. In reality, however, this is an erroneous view, for analysis has proved the waters at such periods to be purer than when the level of the ground-water is high.

224.—*If a well is properly steined, is the water rendered permanently wholesome?*

It is not: lining the upper part of a well with cement does not *permanently* prevent the access of subsoil water impurities. The soil around the well may act efficiently as a filtering medium for a time, but eventually its powers in this respect like those of all other filtering media, become exhausted, and when this stage is reached, all the soil surrounding the well is contaminated. The result then is, that instead of removing the impurities of ordinary subsoil water, it adds further to them, by giving up some of those which it had previously removed.

225.—*What is the usual source of contamination of wells in country places?*

The neighbouring cesspits—a cesspool often literally emptying itself into the well. In the case of deep wells and springs there is less likelihood of contamination than in the case of shallow wells. The chief danger arises from surface drainage, the likelihood of which can generally be estimated from an inspection of the surroundings and from which the wells can generally be protected.

226.—*What are the advantages of deep over superficial wells?*

As a rule they yield purer water; the water is cooler, there is a thicker layer of soil for any contaminating agents to be filtered through, and so there is more complete destruction of any organic matter.

227.—*To what extent may a well be polluted if situated close to a cemetery?*

"The degree to which the purity of neighbouring wells is endangered by a cemetery, and the distance to which contamination may extend, obviously depend in each particular case upon the relative elevation of the respective sites of cemetery and well, and upon the nature and dip of the intervening strata, so that it would seem impossible to lay down a general rule for all cases. Fissured rocks might allow foul matters to traverse considerable distances, while the interposition of a bed of clay or a water-tight fault would shut them off, or the passage through an aerated stratum of finely divided earth would oxidise and destroy them on their way. A dangerous state of things is when graves and wells are sunk near together in a shallow superficial water-bearing stratum of loosely porous nature resting on impervious clay. From experiments made at Dresden by Professor Fleck it would seem that the degree to which wells so situated are liable to pollution is greater when the surface of the subsequent clay bed is horizontal than when it is sloping, even though the slope be towards the well. In the latter case the ground-water is on the move; in the former it is stagnant, and hence the foul matters are concentrated in a smaller volume of water; just as the water of a stagnant pool is more liable to become foul than that of a running stream. It does not appear, however, that the risk to which wells are exposed from the proximity of a properly managed cemetery is in ordinary cases great. A leaky cesspool is a far greater source of danger than a grave. The solid and liquid excretions voided by a human being in the course of a year amount to several times the weight of his body.

"The State Board of Health of Massachusetts . . . give a series of analyses of water from wells in the neighbourhood of cemeteries. Of seven wells in sandy and gravelly soil, varying in depth from 4 to 17 feet, situated at distances respectively of 60, 50, 10, 100, 200, 75, and 100 feet from the nearest grave, and having no other sources of contamination at hand, one only showed undoubted evidence of contamination; this was 10 feet from the nearest grave, the most recent interment, made five and a half months before, being 35 feet distant; the three purest wells were those at 60, 50, and 75 feet distance. The chemical characters by which it may be inferred that the contamination of a particular water is derived from decomposing bodies rather than from sewage, are a high proportion of nitrogenous organic matter and ammonia, or if oxidation have proceeded further, of nitrates and nitrites, relatively to the amount of chlorides present, and also the presence in notable quantity of phosphates.* Outbreaks of diarrhœa are very liable to occur if the water become contaminated with the animal organic matter from the graveyard."

228.—*What are the characters of water from wells sunk in graveyards?*

Water from grave yards contains—ammonium and calcium nitrites and nitrates, and sometimes fatty acids, and much organic

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on issued by the L. G. B. in 1880.

matter. Lefort found a well of water at St. Didier, more than 330 feet from a cemetery, to be largely contaminated with ammoniacal salts and an organic matter which was left on evaporation. The water was clear at first, but had a vapid taste, and speedily became putrid. The water from old graveyards (disused) may show less organic matter, but it will contain large quantities of nitrates, chlorides, etc.*

229.—*How may the yield of wells situated near a river be increased?*

In the case of wells near rivers yielding an insufficient supply, it has been recommended to lay perforated earthenware pipes parallel to the river, and below its fine-weather level, in trenches not less than 6 feet deep, and filled up above the pipes with fine gravel. The pipes end in the well, and water passing from the river, and filtered through the gravel, passes into them.

230.—*What is the course of underground water?*

Precisely the same as that of surface-water—towards the lowest available outlet level; only the slope or declivity of underground is less steep than that of surface-water, in consequence of the greater retarding influence of friction in its passage through the subsoil.

231.—*May wells divert the course of the subsoil water?*

They may; the action of wells in use may sometimes greatly divert the course of underground water, which, but for the influence of wells, would always be towards a lower level or towards a stream.

232.—*Should two wells sunk in proximity to one another be of the same quality as to purity?*

As a rule they should. A-well water sunk near a house, showing a vast difference in composition from a neighbouring well tolerably pure sunk at the same depth in the same soil, must be looked on with suspicion.

233.—*How may we explain sewage contamination in deep wells?*

Deep wells, when protected from surface drainage in their upper parts, are but rarely polluted, even when situated in the centre of towns. But it does occasionally happen, that liquid soakage from sewers or cesspools finds its way into fissures in chalk or sandstone, which conduct it to the water of the well, unfiltered and therefore unpurified, and pregnant with danger to the consumers. Deep wells in Liverpool and other places have been closed for this reason.

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* PARKES' *Practical Hygiene*, 7th Ed.

234.—*When a public water-supply is procured, what should be done in regard to pre-existing wells and surface-water supplies in towns?*

We have no hesitation in stating that all shallow wells and surface-water supplies in the interior of towns generally, should be filled up and permanently closed, as sources of water-supply. Serious contamination is scarcely ever absent. Their continuation as a means of water-supply can only serve to perpetuate the occurrence of many diseases associated with impure drinking-water. We feel convinced that if municipalities adopted this suggestion, they would be carrying out one of the most important of their duties as guardians of the public health.

235.—*What is the opinion of the Rivers Pollution Commissioners upon the admixture of sewage and well-water?*

"Nothing short of abandonment of the inexpressibly nasty habit of mixing human excrements with our drinking-water can confer upon us immunity from the propagation of epidemics through the medium of potable water."*

236.—*Is the cesspool a continuous danger?*

It is; but the danger is increased when the upper part of the well is not properly constructed.

237.—*What are the characters of well-water in proximity to the sea?*

Wells in proximity to the sea generally afford a saline and somewhat brackish water, containing excess of magnesium and sodium salts, without doubt derived from the presence of the salts of sea-water.

238.—*Does sea-water necessarily flow into wells adjacent to it?*

It does not; even when the wells are sunk to a considerable depth below the level of the sea, it must not be supposed that there is any appreciable direct percolation of sea-water into them, for it will be found that the 'set' of the underground water around the well is towards the sea.

239.—*How then may the access of sea-salts to wells adjacent to the sea be accounted for?*

It is more probable that the advent of sea-salts is due to liquid diffusion, the salts diffusing backwards into the well.

240.—*If it were otherwise, what would be the effect?*

The water in the wells would be more than brackish; it would be salt-water.

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*Sixth Report of the Rivers Pollution Commissioners.

241.—*Name any special observations which proved the great distances to which the salts of sea-water may diffuse.*

That sea-salts will find their way into wells situated at a great distance from the sea or a tidal river, is shown by the observation of the late Dr. deChaumont, who found in a place near the Humble River in Hampshire, that the tide affected the water at a distance of 2,240 feet, or nearly half a mile; the well itself being 83 feet deep, and 140 feet above mean water-level. (*'Lect. On State Med., 1875,'* p. 91.) The experience of Dresden is also significant, and to the same effect. The relative temperatures of the river, the ground-water generally, and the water in the tanks in summer—and, further, the hardness of the water in wells near the river—all support the same view as to the origin of the saline impurities of wells situated near the sea.

242.—*What other fact proves this explanation to be the correct one?*

It is known that by pumping from a well near the banks of a river, as the Elbe, the level of the ground-water is depressed over a wide area. It is manifest, too, that were the water of a river to percolate outwards through its bed, this would soon be so silted up by the finely-divided stratum, and that it would not clog the pores of the river-bed, but rather will tend to keep these open. It is remarkable that the underground tanks and galleries, constructed on a false theory, have been so successful as they have generally proved to be.

243.—*What special instance proved the above explanation to be the correct one?*

That the above is the true explanation of the source of water-supply where such underground tanks are constructed is proved by the experience of Toulouse, where the supply of water was largely increased by removing such a tank to a greater distance from the river Garonne, and intercepting the ground-water. The subsoil water invariably rise as we recede from a river.

244.—*What was the theory of supply of tanks, tunnels, and galleries sunk parallel to the bed of a river?*

The theory of these constructions was that water should percolate or filter from the bed of the river into the reservoir constructed for its reception. This supposed percolation can, however, occur but rarely; and nearly invariably it is the underground water, intercepted in its passage to the river, that furnishes the water for use. Should the underground water be not intercepted it gradually finds its way to the river, into and not out of which percolation almost invariably takes place. It is well known, for instance, that the river Thames is in this way largely fed by springs of such ground-water at various points in its course.

245.—*What is the special objection to the domestic use of polluted shallow well-waters ?*

They are usually excessively hard (both permanent and temporary hardness) and therefore unsuited for domestic purposes.

246.—*What is the hardness due to ?*

The hardness is largely due to the polluting liquids which find their way into the well but little being caused by the mineral salts present in the strata through which the well is sunk.

247.—*How may a well or mine be cleared of CO_2 ?*

In the case of a well, a basket of slaked lime may be let down; but in mines, a steam fanner or a jet of steam must be blown through the mine. No one, of course, should be allowed to enter the well or mine till it has been cleared of the carbonic acid.*

248.—*What are the characters of the water of surface or shallow wells ?*

Surface or shallow well-waters, though sometimes comparatively pure, frequently contain a large amount of organic matter. In mossy moorland districts, for example, or in rich vegetable soils, the water may contain from 12 to 30 grains of vegetable matter per gallon, which imparts to it a yellowish or brownish tint; while in marshy districts the amount of organic matter varies from 10 to 100 grains. The saline constituents depend very much upon the geological character of the stratum in or upon which the well is sunk, but in inhabited places these are often masked by the products of excremental pollution. Shallow well-waters are drawn from wells not more than 50 feet deep, and seldom exceeding half that depth. They yield as a rule notoriously bad water. In their ordinary state they yield an excellent breeding place for the germs of disease. They are supplied by] the ground-water, which according to some authorities has important relations with certain diseases. [See No. 146.]

249.—*What is the special danger of shallow well-water in cultivated land ?*

Surface-waters from cultivated land are always more or less contaminated with manurial impurities, and should therefore be efficiently filtered before being used.

250.—*Mention some towns still supplied by deep wells.*

Cambridge, Bury-St. Edmond, Canterbury, Bedford, Scarborough, from oolite, and Coventry, Southport, Scarlington, Burkenhead from new red sandstone.

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* HUSBAND'S *Medical Police.*

251.—*What is necessary before a well recently sunk is brought into use ?*

That the water be analysed by some competent person, and this analysis should be repeated from time to time to assure the consumers of its continued purity, or inform them of any deterioration that may have taken place. It appears to be legitimate to presume that well-water is impure and unwholesome, until it is proved by analysis to be otherwise.

252.—*Is the information afforded regarding the inorganic nitrogen of shallow wells of much practical importance ?*

It is not; because the amount varies within such considerable limits. The proportion may be as low as ·2 or as high as 20 parts per 100,000, according to the extent of previous pollution.

253.—*What is the usual proportions ?*

The proportion usually ranges from 1 to 10 per 100,000 parts of water.

254.—*Is the water of superficial wells of uniform quality ?*

Surface well-water is capricious in quality. Sometimes comparatively pure and wholesome, but usually very impure.

255.—*How may the water of shallow wells be rendered less unwholesome ?*

By puddling the circumference of the well by an impermeable layer of clay three feet in diameter, and for a depth of ten feet, by completely covering the well, by converting all dead wells into pump wells, and by abolishing all privies, cesspits or cesspools, etc., from their vicinity With all these precautions carefully attended to, superficial well-water may be used when no better supply is available ; but even then it is advisable to both boil and filter the water before using it for drinking purposes.

256.—*Can a surface well then be considered safe as a source of supply of drinking-water ?*

A surface well can never be safe however perfectly its sides are cased and made impervious, if there is any pollution of the soil within the distance to which the inverted cone already described extends. Contaminated water will almost inevitably be drawn into the bottom of the well.

257.—*What is the influence of wells upon each other as to yield of water ?*

The success of wells, penetrating deep into large subterranean basins, upon their first completion, has usually led to their duplication at other points within the same basin, and the flow of the first has often been materially checked upon the commencement of flow in the second, and both again upon the commencement of flow in a third, though neither was within one mile of either of the others. The flow of the famous well at Grenelle was seriously checked by the opening of another well at more than 3,000 yards, or nearly two miles distant. [The successful sinking of deep wells in Europe began at Artois, in France, in the year 1126. The name "Artesian," from the name of the province of Artois, has been familiarly associated with such wells from that date, notwithstanding that similar works were executed among the older nations many years earlier. Since the success at Artois, this method has been adopted in many towns of France, England and Germany, where the geological structure admitted of success The French engineers have recently sunk nearly one hundred successful wells in the great Desert of Sahara ; and Algeria and Northern Africa are beginning to bloom in waste places in consequence of being watered by the precious liquid sought in the depths of the earth.]

258.—*Why are superficial wells unsafe as a source of water-supply?*

Because (*a*) they are fed by the subsoil water, (*b*) they are often in proximity with old deep privies, or adjacent to cesspools or drains, the sewage from which may pass directly or indirectly into the wells. [Surface wells near habitations are generally subsoil and rain-water mixed, more or less, with the soluble matters of the soil.]

259.—*What proof have we that the subsoil drainage areas of wells may be very great?*

By the distances at which wells are affected by tides or running waters. A well on the banks of the Hamble, a tidal river, is distinctly affected by the tides, although the distance is nearly forty times the fall—that is, the difference of level between the bottom of the well and mean tide ordnance datum. The pressure of the Rhine has been known to influence a well 1,670 feet distant.

260.—*What may be said with regard to a well-water supply in towns?*

In all houses provided with a public supply the use of well-water should be condemned, because although it may be found to be fit for drinking purposes, the risk of pollution is always greatly increased in towns, on account of neighbouring drains and sewers.

261.—*If wells must be used, what points should be strictly observed and attended to?*

Special attention should be directly given to the water-supply, and any deep ash-pits, midden privies, or cesspools near wells should be removed, and the drains examined. If the water is pumped up by means of a force pump into a cistern, for the purpose of supplying the closets, it will generally be found that the cistern also supplies the housemaid's sink, and that at this tap the water-bottles as well as bed-room utensils, are usually filled.

If the porous stratum in which the well is sunk is of considerable thickness, the underground water being 30 feet or more from the surface, the sides of the well for this depth should be imperviously steined with brickwork set in and lined with hydraulic cement. If this is done, water percolating from the surface must pass through at least 30 feet of soil before entering the well. In its passage through the soil, the organic impurities in the water will be to a certain extent, removed by oxidation

262.—*What precautions should be taken to preserve the purity of well-water ?*

If the water-supply is to be derived from a well, the well and cesspools should be widely separated. In case of accidental leakage it is also necessary that the well should not be near house-drains. To exclude subsoil water, the upper part of a well should be clay-puddled or made otherwise water-tight, and the mouth should be protected against the entrance of surface-water Every well should be ventilated and provided with a manhole for purposes of inspection and cleansing.

263.—*To what distance may the water of the sea affect the quality of well-water ?*

De Chaumont found the tide affecting the level of a well 140 feet above mean water-level, at a distance of 2,240 feet.

264.—*What importance has this point ?*

It bears directly upon the subject of the wholesomeness of water-supply from wells, for it is quite clear that if the effect is so marked, wells may drain cesspools, dung-heaps, middens, and all sorts of filthy places ; and it really appears wonderful, if this be the case, that well-water should ever be fit for drinking, and that more disease is not caused in this way. At the same time we should remember that fairly good water is sometimes obtained from wells that appear likely to be contaminated.

265.—*How may this be accounted for ?*

This depends upon three conditions :—1st, the nature of the soil; 2nd, the direction of movement of the ground-water ; and 3rd, the amount of water drawn from the well. As regards the first, it is clear that impervious soil, such as stiff clay, will shut off the access of water, and consequently of impurity, from strata beyond it. Thus, a layer of clay will successfully keep out surface impurities, if the well is deep enough to pass through it, and is protected in the upper part.

266.—*What is there peculiar about the waters from wells near the sea ?*

They frequently contain so much saline matter as to taste quite brackish, although the organic matter may not be very large.

In some samples from Shoeburyness (analysed at Netley), the total solids ranged from 148 to 312 parts per 100,000 of total solids, the chlorides being from 31 to 93 : mean of six samples—236 total solids and 50 of chlorides. In one sample, however, the albuminoid ammonia was only 0·007 per 100,000, and in five the oxygen required for organic matter was under 0·075 per 100,000. Samples from wells at Gibraltar yield in some cases large quantities of solids—in one instance as much as 338 parts of total solids and 244 of chlorides in 100,000. At Landguard Fort, water from a boring 150 feet deep yield more than 700 parts of solids and 540 parts of chlorides.

267.—*Give an analytical table of waters considered to be very wholesome, stating details.*

POUNDS IN 10,000 GALLONS OR 100,000 LBS.

	Total Solids.	Organic Carbon.	Organic Nitrogen.	Ammonia.	Nitrogen in Nitrates and Nitrites.	Total combined Nitrogen.	Chlorine.	Total Hardness.
Bassenthwaite ...	4·64	·154	·037	·0	·0	·037	1·29	2·83
Buttermere ...	3·56	·127	·040	·004	·0	·043	·89	1·01
Cocker ...	4·62	·069	·022	·001	·0	·023	1·09	2·15
Crawley Burn ...	11 28	·187	031	·001	·0	·032	1·04	6·08
Crummock Water	4·06	·183	·055	·007	·0	·061	·89	1·30
Derwentwater ...	6·56	·218	·043	·001	·0	·044	1·29	1·74
Derwent ...	6·0	·219	·041	·004	·0	·044	1·09	3·37
Ennerdale ..	2·16	·042	·017	·0	·0	·017	·99	1·45
Grassmere ...	4·18	·235	05	·001	·0	·051	·79	2·70
Kent ...	6·48	·149	·020	·0	·044	·064	·90	3·90
Rhine ..	15·80	·108	·012	·003	·0	·015	·20	10·76 hard water.
Rivington Pike...	8·48	·243	·031	·004	·0	·034	1·53	3·72
Rydal ...	4·44	·254	·043	·002	·0	·045	·69	3·10
Severn, above Newtown.	6·60	·123	·016	·003	·010	·028	1·35	3·09
Skiddaw ...	4·34	·132	·024	·001	·0	·025	1·09	3·37
Swanston Water..	12·70	·378	·059	·001	·0	·060	1·39	6·22
Windermere ...	5·78	·299	·076	·00	·018	·096	·99	4·04
Zug ...	13·20	·149	·026	·0	trace	·026	·27	9·03 hard water.
Zürich ...	14·30	·092	·009	·002	·0	·011	·17	10·61 hard water.

* PARKES' *Practical Hygiene*, 7th Ed.

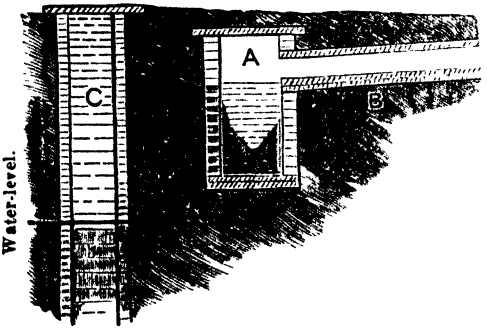
268.—*What should be the limit of organic carbon and organic nitrogen in spring and deep well-water?*

Spring and deep well-water ought not to contain, in 100,000 parts, more than 0·1 part of organic carbon or ·03 part of organic nitrogen. If the organic carbon reaches 0·15 part in 100,000 parts, the water ought to be used only when a better supply is not obtainable.

269.—*How may the contents of cesspools affect the quality of superficial well-water?*

The liquid sewage percolates through the soil and joins the underground water below. As the underground water is slowly but steadily moving along in the direction of its natural outlet, the position of the well, in regard to the cesspool, is all-important. Should the well be above the cesspool, the underground water flowing from the well to the cesspool, the risk of pollution is greatly diminished, so long as but little water is drawn from the well. If the well is below the cesspool, it must infallibly be polluted with the cesspool soakage.

270.—*Give a diagram illustrating pollution of surface well by a cesspool.*



Cesspool leaking into soil, and contaminating the water in well.
A, Cesspool; B, Drain; C, Well.

271.—*What other importance has this relation of cesspools to superficial wells?*

This is one of the reasons why in the sinking of a well the direction of the flow of subsoil water currents is so important, for should they pass beneath houses, near well-privies, etc., the well they feed may become the means of pestilence and death, instead of serving the functions of life and health. The surface soil in India is chiefly of a loamy character, and therefore permits of free percolation of water, which water, as we have before stated, carries with it the impurities of the soil. The descent of the water beyond a certain level is stopped by a layer of clay, but the water oscillates upwards and downwards, and this oscillation helps to increase the degree of saturation with impurities, which are conveyed with the subsoil water to any wells which this subsoil water may feed. Before being opened for use, the water of all newly-dug wells should be chemically analysed. Cesspools are but rarely made water-tight, as they would then require to be frequently emptied. When sunk in a porous soil and merely lined with bricks without mortar or cement, the liquids soak away, and the solids—small in volume—so gradually accumulate, that the cesspool can be closed over and need not be opened for years.

272.—*How may the intermittent pollution of the well be produced in such a case?*

From a rise in the ground-water by which it reaches a cesspool at other times too far above its level to affect it.

273.—*Explain how the pollution of a well takes place when situated close to a cesspool?*

If the underground current be from the cesspool to the well it will be dangerous, but not necessarily so if the flow be from the well to the cesspool. Most wells are dug simply with the view of obtaining water and of having it as convenient to hand as possible; the cesspools are dug similarly, with a view to convenience, except that the demand here is that the liquid contents shall readily drain away. Provided the well furnishes an abundance of water, and the cesspool allows the liquid refuse to soak away, and, on this account, seldom requires cleaning out, there is little concern as to what goes on unobserved beneath the surface of the ground. In the course of time the well-water is discovered to be impure, either by the bad taste, or by analysis of the water which has been grudgingly ordered owing to the suspicious sickness of some who have drunk the water.

274.—*What conditions determine the freedom or otherwise of a shallow well from cesspool or sewage pollution?*

They are:—(1) Its position as to cesspools or other sources of pollution, with regard to the flow of underground water; (2) the amount of depression of water-level in the well which may be produced at any time by pumping; (3) the nature of the soil in which the well is sunk, as regards porosity and the easy passage of water. It is quite possible, if these conditions are attended to, to sink a well that shall be uncontaminable in or near a village, in which the shallow wells generally are horribly polluted with cesspool soakage.

275.—*Suppose a well to be contaminated by sewage, how may the source of pollution be detected?*

If well-water is found to be charged with sewage, the origin of the contamination may be ascertained by throwing a little *chloride* *of lithium* into one of the suspected sources, and, after a day or two examining the water of the well for lithium, with the aid of the spectroscope. This instrument will detect extremely minute traces of the metal, if any happen to have reached the well. If none are found, another possible source should then in like manner be tested.

276.—*How may contamination from surface drains be avoided?*

This form of contamination is preventable to a considerable extent, by constructing a proper parapet wall around the mouth of the well. All wells should be protected by being lined for a depth of 15 feet at least, with a thick layer of hydraulic cement. Even shallow wells would be improved by this means. If the subsoil water sinks below the level of this lining, it has at least been filtered through 15 feet of soil before entering the well. As an additional precaution against direct contamination by surface and subsoil water, the soil around the tube of the well should be puddled to as great a depth as possible. The original excavation should exceed the diameter of the well by 3 feet, to allow of thoroughly well-worked puddle being rammed down. This puddle must be impervious, and the best form of earth for puddle is a light loamy soil with a small share of sand. Surface alluvial soil is useless. From the outside of the basement of the parapet wall, there should be a smooth, sloping, pavement, extending for a distance of 5 feet or so, and this should be surrounded by a masonry channel lined with good cement. This channel should convey all refuse water to a cistern, from which latter it could be periodically cleaned out, or better still, the drain might lead to one of the public drains.

277.—*What relation should the position of the well bear to possible subterranean sources of pollution.*

The well must be sunk in such a position as regards possible sources of pollution, that the underground water flows from the well to the sources of pollution. The distance of the well from such possible polluting sources should be from 100 to 160 times the depression of the water in the well that is ever likely to be produced by pumping, this distance varying with the nature of the soil. The mouth of the well should be closed over, for the water raised by a windlass, chain, and bucket through an open mouth are liable to accidental contamination from refuse being thrown in, or animals falling in. To prevent contamination from impure surface washings, the mouth of the well should be protected by a coping, and the drainage water from the pump conducted away to a safe distance.

Where the level of the underground water is but a few feet from the surface, it is obvious that the surface water, which may contain impurities, has but little chance of being purified by oxidation in its passage through the soil to the well. But the grosser pollutions that shallow well-waters suffer from, come, not from this source, but from leaking drains and cesspools in the vicinity.

278.—*How may the direction of flow of the underground water be determined?*

From the contour of the surrounding country; and this evidence can be confirmed by observations on the height of the underground water at different places, as determined by the height of the water (above sea-level or ordnance datum) in different wells, for the level of the underground water falls as it approaches its outlet, giving rise to a curve.

279.—*What is the relation between the height of the subsoil water and the depth of the water in the well?*

When much water is removed from a deep well, the level of the water in it descends below that of the subsoil or ground-water. The subsoil water now directly feeds the well and flows towards it in such a way, that the area of soil draining its water into the wells forms a sort of pyramid with the apex downwards, the apex corresponding in size with the calibre of the well itself. The result is that all the soil that is embraced in the area covered by the base of the pyramid drains its water into the well. Further, the impurities of any foul ponds, and filth deposits within its reach, are washed into the well In the case of some wells the larger the quantity of water drawn from them the larger the base of the drained area, the greater the amount of subsoil water entering it, consequently the greater the degree of contamination.

280.—*How may we determine the permanency of supply in a well?*

In an inhabited place by enquiry of one of the old neighbouring inhabitants. In an unoccupied area, by observing the nature of the surrounding country. [A yield at the foot of hills is probably perennial.] Should there be an abundance of CO_2 in the water, this is a guarantee to the permanency of the well as it is probably replenished from some subterranean lime-stone reservoir—chalk beds have, as a rule, large underground collections of water: increase in temperature in the water is likewise a sign of permanency.

281.—*Why do surface wells often dry up in summer time?*

Because they are dependent on the subsoil for the water-supply.

282.—*What effect may the sinking of a deep well have upon neighbouring wells?*

It may exhaust the supply of all the neighbouring shallow wells for 2 or 3 miles as well as all the cesspools.

283.—*What was the opinion of the Rivers Pollution Commissioners in regard to water-supply from the Thames and other rivers from deep wells?*

The last Royal Commission which had to do with water-supply—namely, the Rivers Pollution Commission—spoke strongly in favour of abandoning the Thames and other rivers altogether, and thought it feasible to obtain the entire supply for the Metropolis from deep wells within a thirty-mile circle. That this would be done without decreasing the volume of the existing streams, which are in part supplied by springs from the same formation, they do not pretend; but they assert that the water thus obtained would certainly be wholesome; while the river-water is, to say the least, undesirable as a beverage

284.—*What may be said with regard to a well-water supply in towns?*

In all houses provided with a public supply, the use of well-water should be condemned, because, although it may be found fit for drinking purposes, the risk of pollution is always greatly increased in towns on account of neighbouring drains, and sewers.

285—*What peculiar property is common to the water from all deep wells?*

One feature, which is common to most of the deeper wells, is that of the elevated temperature of the water. It is well known that the temperature of the earth increases somewhat regularly from the surface, and the effect of this is felt upon the waters which are obtained at considerable depths. The temperature of the water which flows from the widely-known well at Grenelle, Paris, which is about 1,800 feet deep, has a temperature of 27° C. (80° Fahr). The water of an artesian well in Louisville, Kentucky, which is 2,086 feet deep, has a temperature of 76·5° Fahr. There are, however, some wells which seem to form an exception to this rule, and different wells do not show the same rate of increase in temperature from the surface downward Of course a water with a temperature of 80° Fahr.. while admirably suited for some purposes, is not fit to drink unless artificially cooled.

286.—*Why are deep wells being now abandoned in as a source of water-supply in large towns?*

Because they are found to be insufficient for the wants of a rapidly-increasing population, and obviously cannot be multiplied within a given district beyond certain limits, because every single well drains a surrounding area of some considerable extent. For large isolated buildings, however, such as lunatic asylums, workhouses, and prisons, they usually supply the whole of the water required and in selecting a site in the country for any such building, the possibility of obtaining the requisite water-supply, and the cost at which it can be procured, are points of the first importance.

287.—*What is the usual source of supply in small districts and what in general terms may be said against this supply?*

In small urban and rural districts surface wells, whether as ordinary pump wells, draw wells, or shallow dip wells, constitute the usual source of supply, and though they may naturally yield a wholesome water, the surrounding soil often becomes so saturated with impurities that it is next to impossible to prevent their pollution.

288.—*Are deep wells open to this objection ?*

No, because they are generally sunk through an impervious stratum, which prevents the infiltration of any surface impurities, and at the same time serves to keep down the water in the porous strata beneath.

289.—*Does a much frequented and used well always contain pure water ?*

That a well is popular as a source of drinking-water is no guarantee to the purity of its water. The water of wells containing organic matter undergoing decomposition frequently has a peculiar, but not unpleasant taste, and the slightly sparkling appearance given to it by the carbonic acid formed in the decomposition of the contained organic matter, gives it the specious characters of a good water, and induces people to seek a particular well in which this process is going on.

290.—*What is the risk of storage of deep well-water ?*

It has been found in many cases that there is great liability of vegetable growth when the water is exposed to air and sunlight, so that, if it becomes necessary to store the water before the distribution, covered reservoirs must be used for the purpose, at least in warm climates, and it should be consumed before such growth can occur.

291.—*Do several borings in one locality or in juxtaposition materially increase the yield of water supplied ?*

Practically, it is found that one boring adds to the supply of a well nearly as much as several. Thus in the Bottle well at Liverpool, with 16 bore-holes, some of which were 600 feet deep, Mr. Stephenson found that when all were plugged up but one, the yield was 921,192 galons per day, and when all were open it was only increased by 112,792 gallons.

292.—*In what other way may the yield be increased ?*

It has been in many cases found that the driving of headings and adits horizontally below the water-level, is more effective in increasing the yield of wells than deepening them.

293.—*How is this explained ?*

By the facts that the area of collection of water is thereby increased, and there is a greater likelihood of striking the fissures from which the largest volumes of water are obtained.

294.—*How do we account for the small quantity of organic matter in deep wells and springs ?*

Very little organic matter survives the exhaustive process of intermittent filtration which water suffers on its way to deep wells and springs. In shallow wells, on the other hand, while much organic matter in the water may be oxidised, living spores and germs capable of propagating disease may survive: the purifying effect of filtration into such wells is therefore not to be depended upon, as it may cease altogether if overtaxed.

295.—*Is well-water from granitic rocks wholesome?*

Yes, as a rule it is exceedingly wholesome as are all waters from rocks of volcanic nature.

296.—*Whence is the greater part of the rural population of England supplied with water?*

Almost exclusively from shallow wells; formerly shallow wells were also the usual sources of supply in towns, but these, in nearly all instances, have now been abolished in favour of public supplies from unpolluted sources. The Rivers Pollution Commissioners (Sixth Report) stated that in their experience shallow wells are almost always horribly polluted by sewage and by animal matters of the most disgusting origin.

297.—*How may we roughly ascertain the depth of the subsoil water?*

The height of water in a well may be taken as a good guide as to the depth of the subsoil water.

298.—*Generally speaking, upon what does the chance of obtaining a good supply depend?*

Upon the nature of the underlying strata, and upon the level of the proposed site. Wells sunk in superficial sand or gravel beds, though yielding a good supply at ordinary times, are very liable to have their yield very much lessened in seasons of drought, unless they are situated at points considerably below the level of the surrounding country, and the same remark applies to surface wells in the chalk districts. On the other hand, deep wells or borings in the new red sandstone, and oolite or chalk formations, usually yield a large and constant supply, because these permeable rocks are so saturated with water that they may be regarded as vast subterranean reservoirs. The deepest artesian wells in the world are those at Grenelle in Paris and Kissengen in Bavaria, the former being 1,800 and the latter 1,878 feet in depth.

299.—*Highly polluted shallow well water may appear to be good: how is this to be explained?*

It is a curious circumstance in regard to the grossly polluted waters of many shallow wells, that they are as a rule clear, sparkling, and very palatable. The organic filth from cesspools and drains, in its passage through even a few feet of porous soil, is filtered and deprived of suspended matters, but without losing its dangerous properties. The shallow well into which the filth percolates is found to furnish a water loaded with ammonia and chlorides—evidences of sewage (urine) contamination—with organic matters, but yet, from its containing abundance of carbonic acid gas, sparkling and palatable. If such a water, however, is put in a bottle and kept in a warm place, it very soon becomes turbid, then putrid, and is found to swarm with bacterial life. Such wells, too, after a heavy rainfall, are very liable to furnish a turbid and foul-smelling water which nobody would think of drinking. The heavy rain washes foul substances in the soil, derived by soakage from manure heaps, middens, privies, or cesspools, straight into the well, no time being allowed for that filtering and partial purification by oxidation which does so much to give the well-water at ordinary times its pure but deceptive appearance.*

300.—*Mention an example of an artesian boring in London ?*

That of the Meux Brewery in Tottenham Court Road, which has a depth of 1,144½ feet.

301.—*Through what strata does it pass ?*

From above downwards:

Gravel	22	feet.
London Clay	63½	„
Woolwich, and Reading beds (sands, clays, &c.)	57	„
Thanet Sand	21	„
Chalk	655	„
Upper Greensand	28	„
Gault	160	„
Lower Greensand	64	„
Devonian	80	„ †

302.—*What is an artesian well ?*

It is a shaft sunk or bored through impermeable strata, until a water-bearing stratum is tapped, when water is forced upwards by means of hydrostatic pressure due to the superior level at which the rain-water was received—it spouts out as an artificial stream. The water from such springs is generally very good and wholesome but lies so deep that it is too costly to bore. Its origin from a widespread area of water accounts for the supply from it being constant. In certain low-lying districts, where a boring is made at a point considerably below the level of the line of infiltration into the water-bearing stratum, the water rises above the surface and overflows. Such overflowing wells, or artesian wells as they are called, were once common in the valley of the Thames. [An artesian well draws the water that is confined beneath the retentive stratum and which is there under high pressure, and has probably flowed from a comparatively great distance.]

303.—*Explain the method of sinking an artesian well ?*

Artesian wells, so called from having been first sunk in the province of Artois, in France, are often of very great depth, penetrating a water-bearing stratum which crops up elsewhere at some higher point; by this means the water rises in the well to the height of the outcrop, so as in some cases to flow considerably above the level of the well-opening. Advantage of this is taken in the process of boring, so that the force of the water is sometimes sufficient to force up the *débris* out of the boring-tube. The plan usually followed is to dig a wide well-hole for some depth, and then to complete it with a long bore-tube of narrower diameter. The water of artesian well is usually good, but its composition is peculiar, as it contains a larger amount of salt than the best spring-waters, and also often a good deal of ammonia. This, however, has nothing to do with recent organic impurity, and may be disregarded. Its aëration is less perfect than that of other waters, particularly in the absence of oxygen, but it contains enough of carbonic acid to make it moderately palatable, whilst a very short exposure to the air enables it to absorb oxygen. [Artesian wells are artificial springs, made by boring deep into the ground, until a layer of water is struck which at some part has a higher level; the water rushes up to the surface, or at least to the level of its highest point. From the great depth of such wells, the water is generally free from any dangerous impurity. It is sometimes hot, however, and is nearly always badly aërated, and consequently not very palatable until after some exposure. Boring tools of large diameter have been recently introduced, and these are found less costly, whilst the borings are more easily made. At some new works in the chalk at Southampton, the bore tubes are six feet in diameter.]

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* *Hygiene and Public Health* by LOUIS PARKES, 2nd Ed.

† BURRELL'S *Manual of Water Supplies.*

304.—*What are the characters of artesian well-water?*

The composition varies greatly. In some cases the water is so highly charged with saline matter as to be undrinkable: the water of the artesian well at Grenelle contains enough sodium and potassium carbonates to make it alkaline; there is also often a considerable amount of free (or saline) ammonia. In some cases the water contains an appreciable amount of iron; in other cases, especially when drawn from the lower part of the chalk, or the greensand below it, it is tolerably pure. Its temperature is usually high in proportion to the depth of the well. The aëration of the water is often moderate, sometimes *nil*. These last two points sometimes militate against the employment of water from very deep wells.

305.—*When are artesian wells formed?*

When the stored-up water is confined by an overlying stratum of impervious material, we have the conditions requisite for the formation of an artesian well.

306.—*Into what strata have the most common and the most successful artesian wells been sunk?*

Into the chalk strata.

307.—*Where are artesian wells frequently met with?*

They are very common in the chalk and new red sandstone districts, and are made to increase the yield of the wells. Practically it is found that one boring adds to the supply of a well nearly as much as several. (See No. 292.)

308.—*What is the chief advantage of artesian wells as a source of town-supply?*

In localities where the only water really fit to drink, is stored rain-water or water from some very limited source, it is advisable, if possible, to procure in this way a supply of water which shall answer for most public uses and for many manufacturing purposes, although it is true that a good deal of uncertainty always attends the sinking of the first well which is bored in any particular locality.

309.—*Are artesian well-waters always pure?*

Exceptionally, an artesian well may furnish a polluted water-supply; and some have furnished unmistakable evidence of the sources of their impurities in the shape of dead fish, marsh plants, roots, and seeds; it is supposed that in some of these cases materials have been conveyed in subterranean conduits from great distances.

310.—*What are the essential differences between an artesian and an ordinary well?*

An artesian well is a boring made into an underground body of water, confined under pressure by an impermeable stratum of rock, clay, etc.

This stratum being pierced, the water in endeavouring to rise to the height of its source rises towards or above the surface of the ground.

An ordinary well is sunk down to water not so confined.

The rising of water from a firecock or a strut main illustrates the principle of the artesian well, a pump used for raising water from an underground rain-water cistern shows the action of an ordinary well.

An artesian well hardly becomes polluted in the ordinary sense of the term. The water may, however, be so impregnated with minerals as to be unwholesome, or its temperature may be inconveniently high.

Ordinary wells may be divided into two classes, deep and shallow. Shallow wells gather their supply from the surface or from springs near enough to the surface, to receive surface pollutions and are liable to receive soakings from highly manured fields or gardens, farm and privy middens, dung heaps, shallow cesspools, etc.

Deep wells are such as are sunk to such a depth as to be secure from surface pollutions; the water in them will either have been gathered originally on clean surfaces or have undergone natural filtration.

Such a well may be and has been polluted by another similar well which has been sunk into the same water-bearing stratum and has been afterwards used as a deep cesspool, contaminating the whole body of underground water.

Both kinds of well are liable to pollution from a faulty drain running over the cap or close by top of well. [All ordinary wells should have a thick and well-worked backing of puddled clay behind the brick or masonry lining (or steining), the puddle to extend from the ground surface to a bed of impermeable clay or rock, and also a good covering of puddle over the cap. Drains should be kept at a distance; a surface channel being used to carry off waste from pumps. Shallow wells polluted by soakings direct from surface of ground should be closed.]

An ordinary well does not go through a retentive stratum; an artesian well does—it taps the water situated beneath the stratum, which water is there under considerable hydraulic pressure, and frequently has a distant source of supply.

311.—*Name a few celebrated artesian wells?*

1. That in the Abbatoir in Grenolle near Paris, it is 1,800 feet deep, cost £10,000 to bore, took 10 years to complete, was first lined by an iron tube which has been changed to copper. It yields 656 gallons of water per minute with a temperature of 27°C.

2. That in Kissingen, in Bavaria: it is 878 feet deep, and cost £8,000.

3. The new La Chapelle well in the Paris Basin.

312.—*Describe the new La Chapelle artesian well.*

Its depth is 720 metres, water rising 35 metres above the mouth. It gives 6,000 cubic metres in 24 hours. [It has been proposed to utilise this force to drive a dynamo for the production of electricity. In Florida, the water from an artificial well drives a turbine wheel and dynamo.]

313.—*Mention some of the causes of failures in artesian well borings.*

Rents and faults which abound in some rocks, and the deep ravines and valleys by which some countries are traversed; for when these natural lines of drainage and strata are interrupted, there remains but a small quantity of water to escape by artificial issu Failures may arise from the great thickness of the porous impervious strata, or by the dip of the strata, which may carry off the water from adjoining high lands to dips in the opposite direction, as when the borings are made at a point where the strata incline in a direction inwards or opposite to the base of the cliffs.

314.—*In projecting an artesian well for a town-supply what important points demand attention?*

The geological character of the locality where the boring is to be made, and, as far as possible, the source of the water. Indeed, without a knowledge of the probable character of the particular locality, sinking an artesian well is like investing in a lottery, and hardly justifiable as a municipal undertaking. It is true that many wells are sunk without the advice of competent authority, and some of them are successful; as a rule, they end in failure. The instance of the St. Louis, Mo., artesian well, where £10,000 sunk in the well, is instructive in this connection.

315.—*Are artesian wells used for town-supplies in any instances?*

Yes, for example, the Bottle well, Liverpool, and the well at Grenolle. One portion of the City of London is supplied by the Kent Waterworks Co., which furnishes upwards of 9,000,000 gallons daily, taken from wells in the chalk, in the neighbourhood of the city. The water is quite hard, and hence ill-suited for use in washing, but is clear and colourless and wholesome. There would be no difficulty in softening the water; in fact, a portion of the supply, when some of the wells were in the hands of another Company, was softened by Clark's process to the extent of 1,000,000 gallons per day.

316.—*Mention another difficulty in the use of artesian wells for domestic supply?*

The large amount of dissolved mineral matter which the water from such wells is likely to contain. As almost all rocks are more or less soluble, we should expect that water which had traversed so great a distance underground would be highly charged with mineral matter. Of course the character and amount of the dissolved substances depend upon the nature of the strata passed through. Sometimes the water is absolutely unfit for domestic use, although it may answer for extinguishing fires and watering streets or for irrigation. In other instances, the only difficulty may be that the water is too hard; if otherwie ssuitable, such water may, in some cases, be softened.

317.—*Are artesian wells peculiar to Europe?*

They are not; they are common the world over. In Egypt and in China there are such wells of unknown antiquity, and during the last fifty years great numbers have been sunk in Europe and in America. Of these the larger number have been sunk by private parties in order to obtain water for manufacturing or other purposes. The wells differ greatly in depth and in character of the water.

In some cases the water is so strongly charged with common salt that it can be treated as brine; in other cases the water contains a variety of salts, and is used as mineral water, while in still other cases a soft water fit for all domestic purposes is obtained.

318.—*What are driven or tube-wells?*

They are contrivances in the form of tubes for obtaining water from superficial porous strata by means of borings. They were largely used during the Abyssinian Campaign, where the occupation of any piece of ground was necessarily temporary, the tube being quickly sunk and as quickly withdrawn.

319.—*Describe a driven-well?*

In many localities, a shallow well dug into the ground reaches the ground-water at no great depth, and if the well be carried to the bottom of the water-bearing stratum, an impervious bed of clay is reached, beneath which a second bed of gravel may be found, also water-bearing. This second supply of water may be of very different character from the ground-water proper, and under ordinary circumstances is less liable to pollution. A very common method of obtaining water from such a source, and one that is employed also in some cases in utilizing the ground-water itself, is that of "driven-wells," "tube-wells," or, as they are sometimes called abroad, "Norton," "American" or "Abyssinian" wells. These wells are made by forcing wrought-iron (or galvanized iron) tubes, such as are used for gas or water-pipes, into the stratum from which the water is to be taken. The pipe is generally from 1¼ to 2 inches in diameter and is furnished at its lower end with a wrought-iron or steel point; above this point the pipe is perforated for some distance with holes to admit the water. The pipes are usually driven with a mallet (sometimes by means of a driving weight or "monkey"), and when the top of one tube has come to be at the surface of the ground, a second length is attached. In order for such a well to be successful the deposit into which it is sunk must be quite porous, so as to allow a free passage to the water; this is especially the case where the water is required in considerable quantities for manufacturing purposes or for town-supply.

220.—*Are tube-wells equally liable to contamination with shallow wells?*

They are not; leakage of sewage into such wells is much less liable to occur than into ordinary shallow wells. Nevertheless, when the pump is vigorously worked, sewage may be drawn into the tube from a considerable distance. Of course, tube-wells are not adopted for any but limited supplies of water.

321.—*How are they used?*

An iron tube with a steel nozzle having perforations at its lower end for the passage of water, is driven into the ground by a driving weight or "monkey"; before it has altogether disappeared into the ground another length of tube is screwed on, and this is then driven into the soil. Successive lengths of tube are attached until a depth of 20 to 28 feet is reached when a hand pump is screwed on to the top, and the water pumped out. Difficulty is often experienced from sand blocking the lower part of the tube and the perforations. The sand must be dislodged by clearing tools, or pumped out until a space free from sand is formed around the nozzle, and the water issues clear and bright.

322.—*What is the chief use of tube-wells?*

They are useful for small and temporary supplies, such as may be needed by small bodies of men, when travelling through deserts or unknown countries.

323.—*Describe the London basin in relation to its sources of water-supply.*

Beneath the Lower London Tertiaries comes the chalk, with its outcrop in the chalk hills and downs, north, south, and west of the Thames basin, and many miles from its centre. The outcrop forms a very extensive catchment area for rain, which, percolating through the joints and fissures of the chalk, gives rise to vast reservoirs of subterranean water in the underground extension of this rock beneath the tertiary beds of the London basin. As the London basin is hollowed into the form of a shallow trough, the sides of the trough being the outcrop of the chalk in hills and downs it follows that the water in the chalk is also trough-shaped, and that when wells or borings are sunk into it near the centre of the London basin, the water tends to rise in the boring, and may even overflow at the surface forming true artesian wells. Such wells exist in some of the low grounds of the valleys of the Thames, Wandle, and Lee; but, as a rule, in the chalk borings in the neighbourhood of London, although the water rises, it does not reach the surface. In consequence of the number of borings drawing water from the chalk near London, the water-level has been lowered; and borings have now to be made deeper than formerly. Owing to the joints and fissures in the chalk allowing a free passage of water, the distance which a well or boring drains, when its water-level is depressed by pumping, is very great; and thus borings at considerable distances from one another are mutually affected by continued pumping in any one of them. If a boring in the chalk should not happen to open up any fissures or cracks, it may supply but a limited quantity of water, or none at all. The London basin is interesting as an example of a geological formation with water-bearing strata in different rocks at varying depths from the earth's surface. Most superficially are the subterranean waters in the beds of gravel or alluvium of but slight thickness (10 to 30 feet) upheld by the London clay. These waters supplied the shallow wells which formerly formed so large a part of the water supply of London. After boring through the London clay (100 to 400 feet in the neighbourhood of London) water is again reached—or was before these strata were exhausted—in the Lower London Tertiaries, beds of sand, gravel, or clay of variable thickness (20 to 100 feet) with limited outcrops beyond the edge of the London clay, and more or less surrounding it as they rise from the margin of the basin. The places where these beds are best exposed, and from which they take their names are Blackheath and Oldhaven, Woolwich and Reading, and the Isle of Thanet.

324.—*Why are waters from springs and wells hard?*

The portion of the rainfall which sinks into the ground becomes heavily charged with carbonic acid from the air in the interstices of the soil, and aided by this and by the increasing pressure, it dissolves out lime and various mineral salts from the strata through which it passes on its way to either springs or wells.

325.—*What precaution should be taken before entering an old well or vat?*

A lighted candle should be let down, and if it goes out, the air is deadly. Many lives have been lost through ignorance of this little fact.*

326.—*What gas is often contained at the bottom of old wells, beer vats, and drains?*

They often contain an accumulation of carbonic acid gas, which is invisible and indorous: to enter any place containing ten per cent. of this gas means death.

CHAPTER III.

SPRING AND LAKE WATER.

327.—*Is spring-water wholesome?*

Spring-water is, as a rule, very pure, though it is occasionally hard; that from deep springs is the best of all potable waters, being a naturally filtered water. It is only when springs are superficial, or within reach of contamination, that there need be any apprehension of their creating or transmitting disease. Fountains are imitations of natural springs. Just as water rushes or springs from any artificial fountain that is supplied through pipes from a reservoir at a higher level, no matter how far distant the reservoir may be, so water naturally springs from any crevice or porous spot in the ground that is supplied through the underground channels with rain-water which falls on a higher level, no matter how far distant that higher gathering ground may be. A *spring* of this kind may be met at or near the surface of the ground, or at a considerable depth, and the same physical law is at work here as in the case of artesian wells. In *quality*, the water of springs is much the same as that of deep wells, and it contains usually the same kind of gases and solids. It is clear and sparkling from the dissolved carbonic acid gas which it contains.

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* Vide *Indian Medical Record*, 1891, for case of Carbonic acid poisoning with drowning from this cause communicated by the Author

328.—*Explain the origin of springs ?*

Everyone is familiar with the fact that certain porous soils, such as loose sand and gravel, absorb water with rapidity, and that the ground composed of them soon dries up after heavy showers. If a well be sunk in such soils, we often penetrate to considerable depths before we meet with water, but this is usually found on our approaching some lower part of the porous formation where it rests on an impervious bed; for here the water, unable to make its way downwards in a direct line, accumulates as in a reservoir, and is ready to ooze out from any opening which may be made, in the same manner as we see the salt-water filtrate into and fill any hollow which we dig in the sands of the shore at low tide. A spring, then, is the lowest point or dip of an underground reservoir of water in the stratification. A well, therefore, sunk in such strata will most probably furnish, besides the volume of the spring, an additional supply of water. In other words they are formed by the "cropping out" on the surface of the earth of the impermeable stratum which holds the underground water up, *i.e.*, prevents it from sinking further into the earth. They are natural outlets of underground water, and are usually divided into "main" and "land" springs.

329.—*What are the effects of boring through such an upper impervious stratum of rock ?*

The water-bearing layers of rock may force the water up the borehole to a considerable height. The latent spring is, in fact, tapped and made available for use. Good examples of artesian wells are met with in the Thames Valley, and furnish excellent water-supplies. On the banks of the river Wandle, near Merton in Surrey, the water in such wells rises to the level of a few feet above the surface of the soil, and by means of inverted J-shaped pipes, is discharged in such a manner as turn water-wheels.

330.—*What are the characters of spring-waters ?*

These exhibit every variety of composition, according to the geological formation in which they arise. As a rule the waters from all springs are alkaline, and they contain in solution more or less carbonates of lime and magnesia; those from the chalk are particularly hard, but organically pure. Deep springs are very constant in their composition, and do not exhibit markedly signs of seasonal variation.

331.—*Why are springs often intermittent ?*

They are often intermittent, ceasing altogether to flow during the summer, when the underground water is exhausted, and beginning again in the autumn, very soon after percolation commences. Intermittent springs are also formed where a valley cuts across the highest levels of a large volume of underground water, so that the spring flows only for a short period of every year—usually in February or March—when the highest water line of the underground water is tapped by the depression of the valley. The reason of this appears to be, that the soil is able to evaporate about 12 inches of rain in the six summer months. If the summer rainfall is much less than 12 inches, there is no percolation at all; but if the rainfall exceeds 12 inches, the difference percolates, and helps to replenish the underground waters. In the chalk, about 37 per cent. of the entire rainfall percolates; in the new red sandstone about 25 per cent.; in the magnesian limestone 20 per cent; whilst in the loose sands and gravels about 90 per cent. of the rainfall is said to percolate.

332.—*What are intermittent springs, or "bournes," as they are technically termed?*

They were formerly supposed to be formed by natural siphons, emptying from time to time underground reservoirs of water; but no such siphon emptying any underground reservoir has ever, in fact, been discovered; and all the phenomena connected with these springs can be satisfactorily accounted for on simpler principles. Such springs are usually found near the chalk, as, *e.g.*, near Croydon, and at Assendon.

333.—*Under what circumstances are springs good sources of water-supply?*

Springs afford good sources of water-supply for small communities, such as villages. Main springs are better than land springs, both because they yield water throughout the entire year, and because they are less liable to accidental pollutions, the great thickness of strata, through which the water percolates, from the surface, effectually oxidising any organic impurities it may contain. Such spring-water is usually clear and sparkling, well aërated, and of nearly constant temperature throughout the year. It generally contains more or less of the salts producing hardness, and is, therefore, though palatable and wholesome for drinking, less suited for washing, cooking, and manufacturing purposes, than the soft waters. ["If the student should like to see natural springs yielding many millions of gallons of purest water all the year round, flowing quite unused, he should visit the valley of Basingstoke, and investigate the springs of the contributories of the river Loudon."]

334.—*What are land springs?*

Land springs are springs of water formed by the percolation of water through superficial porous soils, such as sand, gravel, or alluvial earth, overlying impervious strata, such as clay. Where the two strata—the impervious and the pervious—crop out to the surface, or when the line of junction in the two strata is tapped, a land spring appears.

335.—*Under what circumstances are such springs frequently met with ?*

In the carrying out of drainage and sewerage works and during the sinking of wells. Their yield of water is uncertain and precarious depending upon the extent of available porous-collecting area, which may be small. They are, however, frequently replenished by the percolation from heavy summer showers which do not affect deeper springs and wells; but they are also affected by season, the yield of water increasing during the winter months, October to March, and decreasing during the summer months, April to September.

336.—*What precaution is necessary in adopting a land spring as a source of water supply for a house ?*

The yield of water at one particular period of the year—especially the yield in the spring—cannot be relied on as to quantity. The autumn yield is a safer guide to the abundance of the available supply. It is always safest to gauge the spring several times during the year, and more especially during the summer and autumn seasons.

337.—*Where are these springs chiefly met with ?*

In regular geological formations, such as the chalk and greensand.

338.—*What are main springs ?*

Main springs are those deep-seated springs whose source is the main water percolating through great thicknesses of porous rock overlying an impervious stratum, and frequently the collecting area is remote from the spring itself.

339.—*Give an example of a locality in which such springs are abundant ?*

As an example it may be stated that the Thames Valley is surrounded by such springs, and the earliest municipal enterprise of the citizens of London for the conveyance of pure water to the City, had for its object the copious springs at the head of the valley of the river Lea.

340.—*How may pollution of springs be prevented ?*

To guard against pollution, the surface of the soil around the point of delivery of a spring should be walled in, and the water conducted to the surface by a short pipe. In some cases it may be necessary to collect the water issuing from a spring, and to store it in a reservoir before distribution to the houses of the consumers.

341.—*What special point deserves attention when depending upon a spring for water-supply?*

The seasonal variation in the flow. If the selection is made early in the year, it may be found in autumn that the yield of the spring has been reduced to such an extent as to be altogether insufficient for the supply of the house.

342.—*Should a spring be depended upon as a source of supply?*

Unless the yield of a spring is very much in excess of the supply required, it is never safe to depend upon it until its yield in autumn has been ascertained, and even then one may be misled unless close regard is paid to the nature of the season—that is to say, whether or not the rainfall has been such as to cause an unusual amount of percolation.

343.—*In estimating the prospective yield of an untried spring what special datum should be considered?*

The rainfall of the neighbourhood; for although the sources of deep springs are often in one sense mysterious, *viz.*, that the water which feeds them percolates from great distances, and that it is often very difficult, if not impossible, to point out the precise locality where the rain which supplies this water passes into the ground; at the same time the fact is well established that the supply is due to rain falling on the surface of the ground somewhere, and is limited by the amount of this rain, so that any expectation as to the amount of water which can be obtained from deep boring, without taking this circumstance into account, will very likely result in disappointment.

344.—*What situations yield the best springs from a hygienic point of view?*

Those are to be hygienically preferred which issue out of the ground at the foot of extensive mountains or plateaus, formed of rock penetrable to water, such as sandstone or chalk.

345.—*Is there any relation between the quality of spring and deep well-waters?*

There is; spring-waters present much the same characteristics as the water from deep wells sunk into the same strata as those from which the springs issue. The oolitic rocks consist largely of carbonate of lime, and being porous and absorbent like the chalk, are capable of holding enormous volumes of underground water.

346.—*What substances may be contained in spring, river, and well-waters?*

They vary. There may be suspended matters, mineral, vegetable, or animal; dissolved gases, *viz.*, nitrogen, oxygen, carbon dioxide, and in some cases hydrogen sulphide, and carburetted hydrogen; and dissolved solid matters, consisting of lime, magnesia, soda, potassa, ammonia, iron, alumina, combined with chlorine, and sulphuric, carbonic, phosphoric, nitric, nitrous, and silicic acids. More infrequently, or in special cases, certain metals, as arsenic, manganese, lead, zinc, and copper, may be present.

347.—*Why are deep spring-waters so pure?*

Because deep spring-waters have undergone a very perfect natural filtration.

348.—*Is the flow through fissures in chalk ever utilised as a source of supply?*

Occasionally the flow of underground water through fissures in the chalk is employed to furnish an abundant water-supply, which may be of considerable organic purity, as for example, at Brighton, where the necessary works were devised by Mr. Easton.

349.—*From what other sources besides underground springs may drinking-water be obtained?*

On the Continent of Europe, and also in America, it is not uncommon to obtain supplies of drinking-water from underground tanks, tunnels, and galleries sunk parallel and in proximity to the bed of a river. At Brighton, and other places on the sea-coast, little streams of water may be seen flowing seawards from the higher part of the foreshore. These are commonly but erroneously supposed to be formed by sea-water which has been dammed back into the porous strata at high-water. But when tested these streamlets are found to be composed of fresh water.

350.—*On the whole what may be said of the quality of spring-waters?*

Generally, it may be said that spring-waters, if not of a thermal, medicinal, aperient, or chalybeate character from the too great depth or unusual nature of their constituents, furnish pure and excellent supplies of water.

351.—*What may be said of deep well and spring-water as sources of supply?*

That preference should always be given to spring and deep well-water for purely domestic purposes, over even upland surface-water, not only on account of the much greater intrinsic chemical purity and palatability of these waters, but also because their physical properties render them peculiarly valuable for domestic supply. They are almost invariably clear, colourless, transparent, and brilliant, qualities which add greatly to their acceptability as beverages; whilst their uniformity of temperature throughout the year renders them cool and refreshing in summer, and prevents them from freezing readily in winter. Such waters are of inestimable value to communities, and their utilisation and conservation are worthy of the greatest efforts of those who have the public health under their charge.

352.—*What are the special character of waters of springs from chalk districts?*

Spring-waters in the chalk districts are all more or less "hard," and many of them contain such a large amount of calcium carbonate in solution as to be unfit for washing purposes.

353.—*How much oxidised nitrogen is there in springs and deep wells?*

Water from springs and deep wells contains upon an average about 5 parts of oxidised nitrogen per million, shallow well-waters from 2 to 200 parts.

354.—*How may we measure the yield of a spring?*

"A spring is measured most easily by receiving the water into a vessel of known capacity and timing the rate of filling. The spring should be opened up if necessary, and the vessel should be of large size. The vessel may be measured either by filling it first by means of a known (pint or gallon) measure, or by gauging it. If it be round or square, its capacity can be at once known by measuring it, and using the rules laid down in the chapter for measuring the cubic amount of air in rooms The capacity of the vessel in cubic feet may be brought into gallons if desirable, by multiplying by 6·23 If a tub or cask only be procurable, and if there is no pint or gallon measure at hand, the following rule may be useful:—

Take the bung diameter in inches, by measuring the circumference at the bung, dividing by 3 1416, and making an allowance for the thickness of the staves; square the bung diameter, and multiply by 39. Take the head diameter in inches by direct measurement, and square it, and multiply by 25. Multiply one diameter by the other, and the product by 26. Add the sums, and multiply by the length of the cask in inches; then multiply by ·00031473, and the result is given in gallons."*

355.—*What is the level of the underground water in relation to the sea-coast?*

The head or pressure of the underground water is always forcing, or tending to force, the underground water out of the rock at the point where the level of this comes out of the foreshore, whence at low-water the issuing water becomes visible. In winter the water-level in the soil forms a steeper declivity than in summer, when the underground water stands at a lower level in the subsoil. By sinking galleries into the chalk behind Brighton, and parallel with the line of sea-coast, down to a level with the low or summer level of the underground water, the rills of this constantly passing seawards through the fissures in the chalk rock are tapped, and utilised for water-supply. Further examination shows that where the coast is formed of pervious strata, as, for example, chalk, the level of the underground water forms a curve, beginning at a point between high and low water-level, and rising as the sea is receded from.

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* PARKES' *Practical Hygiene*, 7th Ed.

356.—*Are such sources always reliable?*

In adopting such a source of water as has been described, great care is previously necessary to ascertain that the water is uncontaminated, since fissures in the chalk are liable to serve as conduits for sewage from great distances; and it is these chalk fissures which often render a water-supply drawn direct from the chalk a polluted or suspicious one.

357.—*What natural waters are best for scrofulous constitutions?*

Those waters containing iron in combination with other salts.

358.—*Which is the strongest chalybeate spring in the United Kingdom?*

That of Trefrew, in Carnarvonshire, is probably the strongest. It is especially useful in chlorosis or 'green sickness,' or poverty of blood in young girls.

359.—*What are the special characters of Friedrichshall water?*

'Friedrichshall water' is useful in congestion of the liver and kidneys, and as an aperient in constipation of the bowels. Half a pint before breakfast will act as a brisk purgative.

360.—*In what conditions are Vichy waters useful?*

'Vichy waters' are useful in debility of the digestive organs, in gravel, and in gout. Half a pint to two pints may be taken daily.

361.—*What waters are best for gouty and rheumatic people?*

Those just mentioned are of great benefit and being aperient in action, they suit plethoric people likewise.

362.—*Mention a natural water good for persons who have liver disease due to tropical climates?*

The waters of Cheltenham are useful in the diseases of the liver in those who have resided in India and other tropical climates.

363.—*What are the special characters of Hunyadi Janos water?*

'Hunyadi Janos' is a strong purgative water, useful in obstinate constipation and congestion of the internal organs.

364.—*What are the Bath Springs useful for?*

They are very beneficial in rheumatic affections, more so externally than internally. [The hot springs of Bath were known in the time of the Romans.]

365.—*What are the characters of Lake-water?*

Lake-water, especially in mountainous districts composed of the older rock formations, is generally very soft, containing little mineral matter ; but as it is essentially a stagnant water, and as all lakes receive the washings of the districts in which they are situated, the amount of organic nitrogenous matter is sometimes very considerable. Any excess, however, of peaty matter in solution may be materially lessened by filtering through sand. Lake-water resembles river-water, as lakes are fed by rivers, but may contain much vegetable organic matters from their being stagnant.

366.—*Why are Lake-waters favourite sources of supply?*

Because fresh water lakes and deep ponds, whose watersheds have extents equal to at least ten times their water surfaces, are ordinarily, of all natural sources, least liable to objectionable impregnation in harmful quantity When such waters have been imprisoned in their flow, by the uplifting of the rock foundations of the hills across some resulting valley, or by more recent crowding by ice-fields of masses of rock and earth debris into a moraine dam, they are bright and lovely features in their landscapes. and favourite sources of water-supplies. When such waters are deep, and have a broad expanse and bold shores, nature is ever at work with rain and wind and sunshine maintaining their natural purity and sparkle.

367—*What are the chief requisites in lakes as sources of supply?*

The prime requisites in lakes, when to be used for domestic supplies, are abundant inflow and outflow, that will induce a general circulation, abundant depth, which will maintain the water cool through the heats of summer and hinder organic growth : and a broad surface, which the wind can press upon, and roll, and thus stir the water to its greatest depths. These are features opposed to quietude, shallowness, and warmth, which are promoters of excesses of vegetable and animal life, accompanied by a very objectionable mass of vegetable decay and animal decomposition. Fortunately, the shallow waters are oftenest at the upper ends, opposite to the usual points of draught from the lake, or in indented bays, along the sides whence their vegetable products are least liable to reach the outflow conduit.

368—*What are impounding lakes?*

When supplying lakes have moderate drainage areas in proportion to the total volume of water required from them, it is then necessary to place the draught conduit below their natural surface, or to raise their natural surface by a dam at their outlet, to avail of their storage, thus in a degree changing their condition of nature into the artificial condition of impounding reservoirs.

CHAPTER IV.

RIVER-WATER.

369.—*What are the special characters of river-water?*

River-water is in most cases softer than spring or well-water. It contains a smaller amount of mineral salts, but is often largely impregnated with organic matter on account of the vegetable debris and animal excreta which find their way into it. Its constant movement, however, facilitates the oxidation of organic impurities, and this purifying process is aided to some extent by the presence of fresh-water plants. It contains about $\frac{1}{25}$ of its volume of gases which are evolved on boiling or freezing. The amount of mineral matter varies from a few grains in exceptionally pure, to 150 grains to the gallon, according to the amount of impurity to which the water is exposed.

370.—*What are the various forms of impurities met with in river-water and what are their effects?*

River-water is more or less impregnated with decomposing organic material, as well as with the various saline and mineral constituents of the soil washed into the rivers. They are also contaminated, not only by the refuse of cities and towns, but also by the different specific deleterious waste from chemical and other manufactories. This often occurs to such an extent as to kill all fish in the river; but except in such special cases, the amount of foreign matters is reduced to a minimum by dilution and the continual flow of the stream, and also, it is considered, by the oxygenating effect of vegetable life, and from exposure to the air. Some of the purest water is obtained from some of the lochs of Sweden and Norway, and from granitic districts, which are practically free from organic material, and contain not more than from five to ten grains of saline matter to the gallon. Some rivers contain from 30 to 40 or 50 grains in the gallon. The most impure and dangerous water is that which comes from marshy districts, and from stagnant pools. Carbonates and sulphates of lime and magnesia are among the chief saline matters in waters otherwise pure, and when these are in excess the water is said to be hard, curdling soap, and unfit for washing, though not necessarily for drinking purposes. The purest waters are always soft. When any amount of nitrates are present, it is a sign of contamination by animal or other organic matters; and when saline matters in great excess are present, the water may be unsuited for particular constitutions, though not otherwise objectionable.

"Except in rare cases, water which holds in solution a perceptible proportion of organic matter becomes soon putrid, and acquires qualities which are deleterious. It is evident that diarrhœa, dysentery, and other acute or chronic affections have been induced endemically by the continued use of water holding organic matter in large proportions, either in solution or in suspension. It is admitted, as the result of universal observation, that the less the quantity of organic matter held by the water we drink, the more wholesome it is."

"No one has conclusively shown that it is safe to trust to dilution, storage, agitation, filtration, or periods of time, for the complete removal from water of disease-producing elements, whatever these may be. Chemistry and microscopy cannot and do not claim to prove the absence of these elements in any specimen of drinking-water."

"It is a well received fact, that decomposing animal matter in drinking-water is a fertile producer of intestinal diseases."

371.—*What are the characters of river-water?*

River-water is usually impure and unwholesome. Every river is more or less polluted. They all contain earthy matter. In the largest rivers and those that flow rapidly, the water may be fit to use after filtration. They would all contain drinkable water were they to be kept in their natural state. When people begin to build a village or town, they usually do so on the banks of a river or near some water source; and we know that whenever people gather together in large numbers, they pollute the water-supply if it be from wells, tanks, or rivers. If many such towns or villages are on the banks of a river, the water flowing by the lowest towns will be altogether poisonous. The water of rivers in the vicinity of all large towns and cities is grossly contaminated by decaying animal and vegetable substances.

372.—*How may the substances of polluting rivers be classified?*

Into:—A. Organic: B. Inorganic.

Organic: Sewage, Effluent drainage water from houses, manufactories, etc.

These all agree in holding organic matter, more or less putrescent, in suspension, and the remedy is to prevent their discharge into the river or stream until they have been subjected to some sort of purification such as might be attained by:—

Intermittent downward filtration, or broad irrigation.

Inorganic: Various salts met within the geological strata through and over which the water has flown.

373.—*What are the effects of the pollution of rivers by sewage?*

1. Renders the water undrinkable by man. 2. Poisons fishes. 3. Is hurtful to animals. 4. Offensive to senses. 5. Creates disease by drinking. 6. Effluvia sometimes cause disease.

374.—*Is river-water softer or harder than that in its tributary streams?*

Generally, it may be stated that a river-water is less hard and saline than the water of its tributary streams in the lower part of its course, but it may be much harder and more saline than the waters of the upper tributaries, if these flow from a country abounding in igneous rocks. The chalk held in solution by carbonic acid in the contributory springs becomes in part thrown out of solution by the escape of carbonic acid on the exposure to atmosphere during flow in the river, and this tends to diminish the hardness of the water.

375.—*Are the characters of river-water uniform ?*

They are not; for they vary considerably even in different parts of the same river. Fed from a variety of sources, river-water is even more complex in its constitution than spring-water, it is also more influenced by the season, and by circumstances connected with season, such as the melting of snow or ice, rains and floods, etc. The water taken on opposite sides of the same river has been found to differ slightly in composition. (PARKES' *Practical Hygiene.*)

376.—*What are the causes of variation in the characters of river-water at different sources ?*

Nearly all large rivers are charged with silt during the rains. The upper part of their course, where the natural fall of the country is great and the flow of the river or stream high, this salt is carried forward by water holding it in suspension, and the action on the stream is generally erosive, and tends to lower the bed, but as the river reaches the plains below, the velocity gradually diminishes, and at last falls below that necessary to carry on the silt which thus becomes deposited. The effect of this is to raise their beds and cause them to be constantly shifting their course, and also to raise the ground on both sides of their banks often for a considerable distance by successive deposits of silt when they overflow their banks. [Most river-waters partake of a mixed character, for they are derived both from deep springs and from the rainfall flowing off the watershed through which the river runs. The composition of river-water exhibits distinct seasonal variations. At times of greatest rainfall a river is most impure, and at times of least rainfall most pure.]

377 —*What are the objections to river-water ?*

1. The increase of temperature of the water in summer; but this disadvantage may be obviated by the use of ice, and in England this is not a weighty objection as the mean annual temperature of river-water is not high.

2. Turbidity at certain seasons especially at freshets, causing the silting up of clay and other forms of mineral matter and organic *debris.*

3. The water is coloured if from peaty localities.

4. Pollution from sewage and from the solid and liquid refuse from manufactories.

The objection to the river being a carrier of sewage and a source of water-supply is obvious.

378.—*May we obtain a good supply of water from the "Subterranean lakes" adjacent to rivers?*

We may; it is a well known fact that bordering upon all rivers there are found at intervals narrow plains of gravel or sand brought down and deposited there by the river under the varying positions of its channel way. When these beds of gravel extend to a depth below the bottom of the neighbouring stream, they will always be found saturated with water which is partly, at least, derived from that stream, and however turbid the water of the river, this underground flow will always be found clear, provided that we tap it at a reasonable distance from the channel way.

379.—*What is there peculiar about mountain river-waters?*

They are hard, containing salts of lime and magnesium, which are washed out of the soil in the bed of the river by the action of the excess of CO_2, dissolved in the river-water.

380.—*What is the average hardness of this water?*

Fifteen degrees (chiefly due to chalk).

381.—*What are the more important inorganic impurities added to rivers?*

The inorganic metals from mining operations and metal manufactories, and, of course, the salts dissolved out of the bed of the river.

382.—*Under what conditions do streams yield a good and a bad supply of water respectively?*

Streams close to their sources, passing through land not cultivated, and devoid of human dwellings, are good sources of water-supply; but streams and rivers passing through cultivated valleys, with towns and villages on their banks, furnish waters which must invariably be regarded as suspicious in quality, and in point of fact such waters are often dangerously polluted.

383.—*What is the effect of the monsoons on the water of rivers?*

During the monsoons the rivers look muddy They then flow with greater rapidity and silt up the *debris* of mineral, vegetable and (often) animal matter from the bottom. At this time also, the rain-water conveys into the rivers a considerable quantity of earth and organic matters.

384.—*How may we effect the removal of the gross impurities from such waters?*

A muddy appearance does not disqualify water for drinking purposes. If the muddy water is allowed to stand in a vessel for a time, the mud goes to the bottom because it is heavier than the water. We can expedite this precipitation by adding a little alum.*

385.—*River-water is hardest near its source: why?*

Because in its onward flow, as it rolls over rocks and uneven surfaces, it is considerably agitated whereby a large share of the CO_2 it dissolved out from the interior of the earth, is evolved, and those lime and magnesium salts which this excess of CO_2 held in solution are in consequence precipitated.

386.—*What difficulty is experienced in the Hoogly River (Calcutta) in this respect?*

It has been discovered that in the filtering through sand of the Hooghly water at Calcutta, during the rainy season, the fine mud brought down penetrates very deeply into the filters, and rapidly chokes them, in the dry season this does not happen: the suspended matters are arrested, as in England, near the upper surface of the sand. Mr. D. Waldie (*Journal of the Asiatic Society of Bengal for* 1873, Part II., p. 210) explains this by showing that in the rainy season the water contains much less saline matter than in the dry season; it is this saline matter which seems to act on and so cause coherence of the particles of mud, so that they become larger and coarser, and are more easily arrested. In order to remedy this, Mr. Waldie proposes the addition of substances to the water during the rains, which may cause this coalescence; he has tried a great number of experiments with different substances, and on the whole crystallised alum and perchloride of iron are the best; 55·4 lb. of crystallised alum, or 19·15 lb. of perchloride of iron, were found to be necessary for the clarification of one million gallons of muddy Hooghly water during the rainy seasons (PARKES).

387.—*What mechanical disadvantage is there against river-water as a source of supply?*

It has frequently to be pumped up to the reservoirs.

388.—*Does this objection invariably hold good?*

It does not; in the large majority of cases water-supply from a river can be led into storage reservoirs without pumping, that is, by gravitation alone, provided the intake is placed far enough up the river?

389.—*What are the objections to the use of river-water for domestic supply?*

Most streams are open to the objection that they are liable to become turbid at certain seasons, especially in times of freshet, and are also liable to become coloured when the stream flows through a peaty region. The most important objection is their liability to pollution by becoming carriers of manufacturing refuse or of the sewage of towns.

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* The *Strychnos potatorum* is successfully used in Bengal for this purpose. It is usually rubbed on the inner surface of the vessel before filling with the muddy water of the Ganges.

390.—*Does a fouled stream or river affect the health of those dwellings adjacent to it?*

It does. There are strong presumptive grounds for believing that emanations from streams polluted by fæcal matter may be injurious to the health of inhabitants living on their banks. It is stated that in the case of certain observations made on the subject, many of the inhabitants so located were pale, and suffered from dyspepsia, and that cases of fever, when they occurred, were increased in severity. In other instances, however, no such effects have been traced.

391.—*What is the general result of the solvent power of the water of rivers and springs?*

That the water of springs and rivers often contains a great number of constituents—some in very small, others in great amount. Some waters are so highly charged as to be termed mineral waters, and to be unfit for drinking purposes, except as medicines. The impurities of water are not so much influenced by the depth of the spring as by the strata it passes through. The water of a surface spring, or of the deepest artesian well, may be pure or impure.

392.—*What may be said in regard to the temperature of the water of springs?*

The temperature of the water also varies, and is chiefly regulated by the depth. The temperature of shallow springs alters with the season; that of deeper springs is often that of the yearly mean. In very deep springs, and in some artesian wells, the temperature of the water is high.

393.—*How much organic nitrogen in liquid refuse is allowed to be poured into rivers?*

Not more than 3 per 100,000 parts.

394.—*What is there peculiar about the effects of refuse from mines when flowing continuously into rivers?*

The matters and refuse added may choke up the bed and divert the stream.

395.—*How does solid refuse affect rivers?*

It alters the shoaling, channel and bed.

396.—*Why are large manufactories usually situated near rivers?*

On account of the easy access to water for the trade; the easy disposal of the trade refuse; easy transportation of goods, and the available water (hydraulic) power.

397.—*By what means did the Rivers Pollution Commissioners recommend that the effluent be purified?*

Perfect rest in subsidence ponds for 6 hours.

398.—*What is the standard of impurity permitted by the Rivers Pollution Commissioners?*

1. They recommended the condemnation of:—any water containing 1 in 100,000 parts of organic matter, and water containing 3 in 100,000 parts of inorganic mineral matter;

2. Any liquid containing more than 2 parts per 100,000 of organic carbon, 3 parts per 100,000 of organic nitrogen;

3. Any liquid which *exhibits by daylight* a distinct colour when a stratum of one foot deep is placed in a white vessel;

4. Any liquid containing more than 2 parts per 100,000 of any metal, except, *Ca, Mg, K, and Na*;

5. Any liquid containing more than ·05 per 100,000 parts of metallic poisons;

6. Any liquid which, after acidification with $H_2 So_4$ contains more than 1 per 100,000 parts of free chlorine.

399.—*Are the effluents from metallic factories important?*

The pollution from nickel works, iron works, cutlery, brass foundries, and electro-plate factories are, as a rule, unimportant. Nevertheless it should be remembered that the effluent from many metal factories is very acid and corrosive, dissolving cement, and loosening brickwork of sewers.

400.—*What is the remedy for preventing the refuse fluids of mines fouling water of rivers?*

The remedy is rather preventive than curative. Most of the matters are in suspension. The way frequently adopted is to cause the very foul refuse liquids to pass into pits with overflow after subsidence.

401.—*How may the refuse liquids of trades and sewage be purified sufficiently to allow them to pass into rivers?*

1. By subsidence tanks with effluent flowing into river;

2. By means of intermittent filtration and irrigation. It should be specially remembered, however, that these two processes are only applicable to refuse liquids containing animal and vegetable matter.

402.—*The water of large rivers is less impure than that of small; why is this?*

In large rivers the poisons are in a more dilute form, the flow is more rapid, and the water mixes with a great quantity of air,—the oxygen of the air acting as a purifying agent.

403.—*Should sewage be allowed to pass into rivers?*

Certainly not, and especially in the unpurified condition. No river in England is long enough to oxidise any inordinate amount; and mere filtration will not remove the poison, though it may clarify the sewage.

404.—*Explain the origin of villages and towns on the banks of rivers?*

When people begin to build a village or town they usually select a site in proximity with a reliable water-supply. The banks of a river are, therefore, most frequently chosen. In gathering together in large numbers, they pollute the water. If many such towns or villages are on the banks of a river the water flowing by the lowermost villages or towns will be altogether poisonous.

405.—*As a rule where do towns get the water for their population?*

From rivers above the inflow of the sewage. [But the next town lower down must get its supply from their diluted sewage water if it is allowed to flow into the river, which in a large number of cases. is unavoidable.]

406.—*How are the organic impurities of streams got rid of?*

To a certain extent organic impurities in streams are got rid of by oxidation and by the growth of plants and other organisms; but this possibility of subsequent partial purification cannot justify the gross pollution of a stream at any given point. In a few cases the purification is complete, but in no case can there be any certainty of the destruction of specific pollution, a consideration which is especially important when the stream furnishes the water-supply of districts nearer to its mouth. Most of the rivers in manufacturing districts are converted into mere sewers by this misuse, which the Rivers Pollution Act has been powerless to completely prevent.

407.—*How is sewage purified in rivers?*

The oxygen dissolved in the water oxidises the organic matter, the green colouring matter of aquatic plants gives out oxygen in the nascent state, which does the same but more vigorously, the solid and suspended organic matter is consumed by fishes and other aquatic animals, the rest of the organic matter gradually subsides; and lastly the large volume of water contained in the small volume of sewage helps to dilute the organic matter.

408.—*Has running water any power of intrinsic depuration if once rendered impure?*

Many authorities hold that running water has an intrinsic power of purification, that the oxygen of the air dissolved in the water is sufficient to oxidise and render harmless all the organic matter contained. Were the impurities limited, doubtless this would hold good, but on the banks of all large rivers, towns are situated one below the other, so that there is scarcely time for one source of contamination to be rendered innocuous, before others are added. Upon this point an interesting experiment was carried out to show the fallacy of such a view. Distilled water, to which a varying quantity of sewage was added, was caused to circulate automatically in a specially constructed small circular metal drain. After it had traversed the drain a number of times representing a distance greater than that of any river in England, the water was found to be still impure.

409.—*Mention a special instance in which this is well seen?*

The purification of the waters of the river Rhone during their passage through the Lake of Geneva. The turbid and organically polluted water enters the head of the lake, having much the appearance of road-washings, and the clarified and purified water is seen to issue from the lake at Geneva as a beautifully pellucid and magnificently blue stream. [But even in this case the separation of solid particles achieves a further result, for dissolved organic matters are in some way carried down with the deposited mud.]

410.—*What agencies are at work in effecting the depuration of river-water contaminated by sewage or other organic liquid?*

When sewage or other polluting liquids are discharged into rivers, they are more or less diluted with the river-water, the amount of dilution depending on the comparative volumes of sewage and river-water which are thus mixed together. If the river, into which the sewage is discharged, consists of clean and hitherto unpolluted water, the atmospheric oxygen dissolved in it, which is chemically much more active than the oxygen of the air, will, to a certain extent, oxidise the organic matters of the sewage. If, too, the dilution of the sewage with clean water is considerable, plant life is not interfered with, but continues to give off oxygen, re-oxygenating the water and enabling the process of purification by oxidation to continue. No doubt, too, as the oxygen dissolved in the water is used up, and fresh oxygen is absorbed from the air. Besides water plants, minute animals (infusoria, anguillulidæ or water worms, entomonsraca or water fleas, etc.) aid the process of purification by feeding on the organic impurities of sewage. These organisms are found in countless numbers in the polluted reaches of rivers. Fish, too, if the pollution is not sufficiently great to cause much diminution of dissolved oxygen in the water, feed on some of the elements of sewage, and aid in the process of purification; and if the current is sluggish, or in the deep and quiet pools of a rapid stream, the suspended matters of the sewage will be largely deposited. The result of all these processes is that, under certain conditions and within certain limits, streams and rivers which have been polluted are capable of undergoing a certain amount of self-purification. The extent of this is, however unsettled, in other words, its greater or less completeness within a certain distance of flow, is still a matter of doubt. The Rivers Pollution Commissioners (Sixth Report) came to the conclusion, as the result of their experiments, that "the oxidation of the organic matter in sewage proceeds with extreme slowness, even when the sewage is mixed with a large volume of unpolluted water, and that it is impossible to say how far such water must flow before the sewage matter becomes thoroughly oxidised. It will be safe to infer, however, that there is no river in the United Kingdom long enough to effect the destruction of sewage by oxidation." On the other hand, several eminent chemists have expressed their belief that a flow of even a few miles is sufficient to free a river of all trace of sewage contamination.

The truth of the matter appears to be, that under favourable conditions, when the dilution of the sewage with clean water is very considerable, and the oxidation and purification exerted by aquatic animal and vegetable life can have free play, a stream or river especially if it undergoes agitation and exposure to the air by flowing over rapids or by falling over weirs, is capable of being so far purified, that, although it may never quite regain its original purity, it becomes at least very much improved. Practically, however, in England, streams and rivers are not allowed a chance of self-purification. The pollution is almost continuous from their sources to their mouths.'*

411.—*What effect has rise of temperature on this process of depuration?*

A considerable rise of temperature will produce a like result on rivers which are having their purifying powers tested to the height of their capacity. Purification goes on so long as the weather is cool, but with a rise in temperature, bacterial growth is stimulated, and decomposition sets in, replacing the oxidising processes. This happened to the tidal portion of the Thames in the Summer of 1884, resulting in a condition of things which the Royal Commissioners on Metropolitan Sewage Discharge stigmatised as "a disgrace to the Metropolis and to civilization." In the North of England, the [illegible] and Mersey are so polluted with sewage and manufacturing refuse from the towns on their banks, that purification by oxidation may be said not to exist in these waters, which carry their filth and refuse unacted on and unchanged to the sea.†

412.—*It is stated by some that water, stagnant or flowing, once contaminated can never become sufficiently pure to be consumed. How far is this assertion borne out by facts?*

The injurious action of water contaminated by the specific poisons of disease is said by many to be unlimited both as to time and space—that once a water receives even a small specific contam-

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[*] *Hygiene and Public Health*, by LOUIS PARKES, M.D., 2nd Ed.

ination, it is ever afterwards dangerous, no matter how long or far it may flow or percolate. This is a very sweeping statement, and is contradicted by the fact of the proved wholesomeness of many waters that have been specifically contaminated. Indeed, were such an extreme view as this to be true in India, we should for ever be in danger of falling victims to fatal disease, for almost all rivers and wells are so contaminated.

With regard to the origin of certain diseases said to be due to fungi, it is quite possible that it is only when a water containing these germs is undergoing progressive deterioration, and exposed to certain conditions of weather capable of bringing about the multiplication of the germs that these diseases arise.

413.—*Who were the great supporters of the self-purification theory of running water?*

The late Drs. Letheby and Tidy were the strongest supporters of this hypothesis, which has also received the support of Dr. Odling. Nevertheless, it must be admitted that the experience of 1866 with respect to cholera—the last visitation of that disease in England in an epidemic form—is insufficient to enable a satisfactory conclusion to be drawn, affirmatively or negatively; and more recent experience appears to show that a flow of several miles in a river is insufficient to destroy the activity of the poison of typhoid fever.

414.—*What was the opinion of the Rivers Pollution Commissioners in regard to river-water as a source of public water-supply?*

The Commissioners (*Sixth Report*, p. 418), while admitting that the drainage-water from arable lands is preferable to that from polluted shallow wells, apparently were of opinion that river-water is inadmissible as a source of town supplies, a conclusion which is far too sweeping.

415.—*Who were the great opponents of the non-depuration of previously polluted river-water?*

Dr. Frankland and the Rivers Pollution Commissioners, in their celebrated 'Sixth Report' have thrown doubts on the self-purifying power of streams through the agency of free atmospheric and dissolved oxygen, etc.; but this position has been in part at least successfully contested by Odling, Letheby, Tidy, and others; and Dr. Frankland himself has apparently seen his way to modify his previous views as to the oxidising power of dissolved oxygen.

416.—*What is Dr. Frankland's views in regard to the self-purification of running river-water?*

He stated that there is no river in the United Kingdom long enough to purify its waters spontaneously if they have once become contaminated with sewage, a statement to which, without very material qualification, few would venture to subscribe in the present day.*

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* See FRANKLAND'S *Applied Chemistry*, p. 552.

417.—*What would appear to be the true statement of the case?*

The truth appears to be that rivers are able to get rid of their sewage pollution by the combined agencies of oxidation, growth of vegetation, and the activities of organisms such as bacteria and the lower forms of vegetable growth; and there is practical but not absolute safety, if the polluting material be not introduced in excessive proportion, and the river have a free flow of several miles, especially over a rocky bed and weirs, so as to subject the water to agitation and consequent abundant aëration. What has just been said must not be taken to indicate that the pollution of a river-water by filth is of no consequence provided there be a good flow of a few miles before the intake of a drinking water-supply is reached. It would appear from a perusal of the writings of the best-known authorities on the subject that the danger accruing from the use of river-water which has been previously contaminated has been somewhat overrated. Nevertheless we consider, that rivers which have received sewage, even if that sewage has been purified before its discharge, are not safe sources of potable-water.

418.—*Are laboratory experiments on the effects of free oxygen on running-water comparable with the natural processes of oxidation?*

They are not comparable, because the conditions are not similar. In laboratory experiments ordinary free oxygen, and, still less, atmospheric air, oxidise putrescible organic matters when in dilute solution only slowly; under natural conditions, where water is exposed to an enormous and practically unlimited volume of atmospheric air, the result is apparently different, and it is probable that atmospheric ozone and peroxide of hydrogen may have much to do with the effective oxidation of the nitrogenous organic substance present in the polluted waters of rivers. These oxidising agents can have, however, little or nothing to do with the oxidation of organic matters in the soil, and in the water percolating into the subsoil. Here a different agency comes into play.

419—*Is it scientific to term the depuration of river-water a self-purification?*

It is not; the so-called self-purification of flowing water is, strictly speaking, a misnomer, for, in all instances where self-purification occurs, the purification is effected by some other agency, except perhaps in one case—that of the purification of a water by subsidence, or the separation of solid suspended particles by simply allowing the water to come to rest.

420.—*What conclusions did the late Dr. Tidy arrive at in regard to the self-purification of sewage-polluted rivers?*

1. That when sewage is discharged into running-water, provided the primary dilution of the sewage with pure water be sufficient, after the run of a few miles, the precise distance of travel being

dependent on several conditions, the removal of a large part of the organic impurity will be effected.

2. That whatever be the actual cause of certain disease, *i.e.*, whether germs or chemical poisons, the materies morbi which find their way into the river at the sewage outfall are destroyed, together with the organic impurity, after a certain flow; and, lastly, that vegetable matter deposited in the bed of a stream undergoes a fermentative change, and one of the products of this change is marsh gas, so abundantly liberated on stirring the bed of any muddy ditch. This, then, is another mode by which organic matter may be converted into harmless inorganic forms of matter.

The late Dr. Tidy, who was one of the strongest defendants of the potability of river-water, even after the influx of sewage, after a review of all the facts, thus summarised his conclusions: These conclusions were formulated before the bacteriology of specific diseases was developed; but observation appears to show that a flow of 20 miles in a river is not sufficient to destroy the germs of typhoid fever. Dr Barry, in a recent report to the Local Government Board, expresses his opinion that a flow of 40 miles at least is necessary after an irruption of sewage in order to render the river-water a desirable supply for drinking purposes. He bases his opinion on an outbreak of typhoid fever following an irruption of filth into the Tees.

421.—*Is the process of nitrification active in rivers?*

Nitrification, which is effected by one or more micro-organisms, is not a very active process in running-water, and it is a mode of changing organic into inorganic matter, more effectively going on in soils than in rivers and other water-courses. Nevertheless the natural purifying agencies ordinarily going on in streams are in the aggregate considerable, and generally effective.

422.—*How do fishes help to effect the depuration of sewage-polluted streams?*

Where *fresh* sewage flows from a sewer into a stream, the mouth of the sewer becomes the feeding-place of numerous small coarse-feeding fishes, which greedily devour, and convert into food for larger fishes, the scraps of muscular fibre and other *debris* which would otherwise decompose and pollute the stream. Minute particles of solid organic matter may, and probably do, serve as the food of minuter forms of aquatic animal life, and thus indirectly serve as food for fish. [The mud banks of the Thames estuary are the habitat of the fine flat-fish, eels, and molluss which serve the London market.]

423.—*Is putrid sewage similarly consumed by fishes?*

It is not; putrid sewage-polluted streams are shunned by aquatic animals, and it is known that stinking streams do not readily undergo self-purification; for instance, witness the Thames, though here the saltness of the water below London Bridge may cause the water to have a preservative effect on the molecules of undecomposed and decomposing sewage.

424.—*Can we define the extent to which each of these natural processes purify water?*

We cannot. The extent to which subsidence, oxidation, and the presence of animal life are respectively potent in bringing about the purification of our rivers, is at present quite unknown.

425.—*What effect on the purification of river-water have growing green plants?*

Such plants, even those of a low type, are capable under the influence of sunlight, of effecting vast changes in the character of a water. The cleaning out of tanks and ponds, so as to free them from weeds, has been known to render the water of such reservoirs more impure, by depriving them of a most active agent of purification. The oxygen given off by growing green chlorophylliferous plants is probably like other forms of nascent or atomic oxygen, peculiarly active as an oxidiser; and this oxidation of nascent oxygen may be one of the most valuable agents for effecting the oxidation of dissolved and minutely-divided solid forms of organic matter.

426.—*What is the effect of the small quantity of iron contained in all natural waters, and how does putrescent sewage affect it?*

It is probable that the salts of iron, always present in natural waters in very minute quantity, act in some measure as carriers of oxygen. Putrescent sewage reduces these salts to the lower stage of oxidation of ferrous salts—*e.g*, ferrous sulphide; and these, under the influence of dissolved oxygen, become converted into ferric or more highly oxygenated salts, which again give up their oxygen to organic matter, and are again reduced to the state of ferrous salts. Whether this be the proper interpretation of the matter or not, it is possible that free oxygen is capable of effecting the rapid purification of streams, notwithstanding the adverse laboratory experiments of Dr. Frankland. Some think that iodine compounds, also rarely entirely absent from terrestrial waters, act as carriers of oxygen, by their alternate oxidation into iodates and reduction to the state of iodides.

7.—*By what other process is river-waters said to be purified?*

They are also said to be purified by dilution. It is doubtful whether this purification ever takes place, except in so far as an impure water, by admixture with a purer water also well aërated, is furnished with the oxygen necessary for the destruction of impurities. It should not be forgotten, that when a relatively small quantity of a polluted liquid is mixed with a large quantity of water of moderate purity, the added impurity may not increase the impurity of the latter to such an extent as to render its assured detection possible to the chemist.

428.—*What changes occur when the amount of sewage added to the river-water is beyond the power of natural processes to defœcate?*

When the river, into which sewage is discharged, is already much polluted, or if the dilution is not sufficiently great, oxidation and purification are brought to a standstill. The dissolved oxygen is greatly diminished in amount, animal and vegetable aquatic life is injuriously affected or destroyed, and putrefaction sets in. The bacterial agents of putrefaction are the only organisms which can flourish under such conditions; decomposition and fermentation of organic matters are started, with the production of foul gases; the bed of the river becomes silted up with decaying matters, which, buoyed up by gases, occasionally rise to the surface to sink again, and a most serious nuisance results.

429.—*What are the effects of river-pollution by unpurified sewage?*

1. Sewage renders the water undrinkable by man;
2. Poisons fishes;
3. Is hurtful to animals;
4. Offensive to senses;
5. Creates disease if used for drinking purposes—sometimes epidemic disease;
6. The effluvia themselves sometimes cause disease.

430.—*What may be said with regard to permitting sewage to gain access to rivers?*

The use of the same stream as a carrier of waste and as a source of supply is to be deprecated, and, on this account, it is manifestly unjust that one town should be allowed, at its own option, to discharge its sewage into a stream which, lower down in its course, would otherwise afford suitable drinking-water to other towns.

431.—*Give a specific instance of gross pollution of river-water?*

The following is a quotation from one of the English reports with reference to the rivers Aire and Calder:—

"These rivers and their tributaries are abused by passing into them hundreds of thousands of tons per annum of ashes, slag, and cinders, from steam-boilers, furnaces, iron-works, and domestic fires; by their being made the receptacle, to a vast extent, of broken pottery and worn-out utensils of metal, refuse brick from brick-yards and old buildings, earth, stone, and clay from quarries and excavations, road-scrapings, street-sweepings, etc., by spent dye-woods and other solids used in the treatment of worsteds and woollens, by hundreds of carcasses of animals, as dogs, cats, pigs, etc., which are allowed to float on the surface of the streams or putrefy on their banks; and by the flowing in, to the amount of very many millions of gallons per day, of water poisoned, corrupted, and clogged by refuse from mines, chemical works, dyeing, scouring, and fulling worsted and woollen stuffs, skin-cleaning and tanning, slaughter-house garbage, and the sewage of towns and houses."

432.—*How is the volume of flow or discharge of a stream of water expressed?*

In units of volume per unit of time.

433.—*Describe another method of calculating the discharge from stream.*

A much more accurate and satisfactory method is to measure the actual discharge of the stream at the same time that the rain-gauge observations are made, and so to find the actual proportion of available water to total rainfall.

434.—*How may the yield of an averaged-sized stream be calculated?*

In the case of an averaged-sized stream, a rough approximation of the yield may be obtained by taking breadth and depth at several distances in a short section of the channel which is tolerably uniform, and thus ascertaining the average sectional area.

435.—*How is the mean velocity in a stream ascertained?*

The mean velocity of a stream at a given cross section is found by dividing the discharge or volume of flow by the area of cross-section, and is most conveniently expressed in feet per second. In ordinary cases the least, mean, and greatest velocities may be taken as bearing to each other nearly the proportion of 3, 4 and 5. In slow currents they are as 2, 3 and 4.

436.—*What are the three chief ways of measuring the discharge of a stream?*

By weir-gauges, by current metres, and by calculation from the dimensions and declivity.

437.—*Which is the most accurate?*

The use of weir-gauges, but it is applicable to small streams only. [The flow of water in small streams is usually gauged by means of a notch-board. The board must be made to act as a water-tightdam, serving to retain a pond of still-water, the level of which may be accurately ascertained. If the water above the notch-board is still, but has a sensible velocity of approach towards the notch, this velocity must be regarded in calculating the quantity of water passing over. The notch should present to the stream a thin edge formed by chamfering the board on the down-stream side. The height of still-water above the sill of the notch may be ascertained from a scale previously adjusted on a stake driven in the bed of the stream above the dam. The notch should be nearly of the full width of the stream, the better to allow for the passage of larger volumes of water, and there should be a clear runaway from the notch board, to prevent the tail water rising and drowning the notch. Great care must be taken also to prevent leakage round the end or under the bottom of the board. Observations should be taken never less frequently than once a day, and at shorter intervals as the drainage area is smaller and more precipitous, for the falls of rain are then more quickly felt and pass sooner away. The most satisfactory, because the only correct method of ascertaining the flow is, to make it with its variations self-recording. This may be accomplished by any means which will register the variations in the level of the still-water above the notch upon a revolving drum actuated by clock-work. The width of the notch, the head of water, and the time for which that head has been maintained being all known, the quantity discharged during that time may be ascertained by a simple calculation.]

438.—*How may we estimate the yield of a small stream?*

By receiving the water into a capacious vessel of known dimensions and noting the time it takes to fill it. It is important that the estimate be made at the time of the lowest yield of the stream.

439.—*What then are the different ways in which we may estimate the yield of a small stream or water-course?*

When it is required to ascertain the yield of any small water-course with some nicety, it is the practice of engineers to dam up the whole stream, and convey the water by some artificial channel of known dimensions.

1. A wooden trough of a certain length, in which the depth of water and the time which a float takes to pass from one end to the other is measured.

2. A sluice of known size, in which the difference of level of the water above and below the sluice is measured.*

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* *Discharge of water through a sluice.*—Multiply the breadth of the opening by the height; this gives the area of the sluice.

Discharge-area, multiplied by five times the square root of head of water in feet.—The head of water is the difference of level of the water above and below the dam, if the sluice be entirely under the lower level; or the height of the upper level above the centre of the opening, if the sluice be above the lower level.

3. A weir formed by a plank set on edge in which a rectangular notch is cut, usually one foot in width ; over this the water flows in a thin sheet, and the difference of level is measured by the depth of the water as it flows over the notch. Then by means of a table the amount of water delivered per minute is read off. The weir must be formed of very thin board and be perfectly level ; a plumb-line has generally to be used.* This plan of measuring the yield of water-courses is the one now most generally adopted by engineers.

When it is required to ascertain the yield of any small stream, it is usual to employ a weir-gauge to dam up the water into a pond behind, and allow it to flow through a sluice or over a sill of known dimensions. In the case of an average-sized stream, a rough approximation of the yield may be obtained by taking the breadth and depth at several distances in a short section of the channel which is tolerably uniform, and thus ascertaining the average sectional area. The surface velocity may then be taken by noting the time occupied in floating a light object such as a chip of wood over the selected distance, and as four-fifths of the surface-velocity are about equal to the actual velocity, the yield in cubic feet or gallons per second, can be easily calculated.

[We add about ·25 to the rapidity of flow as the float indicates the rapidity of the surface flow and not the actual flow itself which is greatest about the mid depth of the stream. The float should be placed away from the bank as the friction near the bank lessens the velocity.†]

440.—*In making such a calculation what precaution has to be particularly observed ?*

That the numbers multiplied are brought to the same denomination—all in either cubic inches or cubic feet.

441.—*In the case of spring or small river, is one observation as to yield sufficient ?*

It is not ; the yield of a spring or small river should be determined several times, and at different periods of the day.

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* *Discharge of water over a weir 1 foot in length.*—If the weir is more or less than a foot, multiply the quantity in the table opposite the given depth by the length of the weir in feet, or decimals of a foot.

Depth falling over, inches.	Discharge per minute.	Depth falling over, inches.	Discharge per minute.
½	1·70 cubic feet.	2½	19·70 cubic feet.
1	4·82 ,, ,,	3	26·62 ,, ,,
1½	8·84 ,, ,,	3½	38·22 ,, ,,
2	13·63 ,, ,,	4	40·71 ,, ,,

Thus, if the weir measure 1 foot, and the depth of water falling over be 2 inches, the delivery is read at once, viz., 13·63 cubic feet, or 84·9 gallons per minute.

† This method is applicable to both large and small streams.

442.—*Upon what do the characters of water from wells, springs, rivers, and lakes depend?*

The quality and composition of the water derived from these sources depend on the nature of the soil and geological strata through which it has passed, or on the character of its surface-bed or channel. The rain, already charged with carbonic acid in its passage through the lower regions of the atmosphere, becomes still more largely impregnated with this gas when it sinks beneath the surface In some rich soils the amount present in the air contained within their interstices, according to Boussingault, is 250 times greater than the ordinary atmospheric ratio. Aided by the action of the carbonic acid which it has thus absorbed, the rain-water dissolves and decomposes various chemical compounds which it meets with in its underground progress, and often becomes so highly charged with them as to become unfit for ordinary use, as in the case of mineral waters.

443.—*Compare the value of spring, river, and well-water as sources of supply.*

This depends on many circumstances. Spring-water is both pure and impure in different cases; and the mere fact of its being a spring is not, as sometimes imagined, a test of goodness. Frequently, indeed, river-water is purer than spring-water, especially from the deposit of calcium carbonate; organic matter is, however, generally in greater quantity, as so much more vegetable matter and animal excreta find their way into it. The water of a river may have a very different constitution from that of the springs near its banks. A good example is given by the Ouse, at York: the water of this river is derived chiefly from the millstone grit which feeds the Swale, the Ure, and the Nid, tributaries of the Ouse; the water contains only 9 grains per gallon of salts of calcium, magnesium, sodium, and a little iron. The wells in the neighbourhood pass down into the soft red sandstone (Yoredale series) which lies below the millstone grit; the water contains as much as 64·96 grains, and even, in one case, 96 grains per gallon; in addition to the usual salts, there is much calcium chloride and calcium, sodium, and magnesium sulphate.*

444.—*What are glaciers?*

These are rivers of ice draining the high snow fields. [The movement of a glacier is essentially of the same kind as that of a river, the central portions moving faster than the edges. The movement is, therefore, one of degree not of kind. The motion of a glacier has been explained by supposing that the ice forming the glacier is successively fractured and frozen. Thus, "when a glacier is forced over an obstacle, the ice, being brittle, cracks and snaps; but the enormous pressure of the sliding mass behind squeezes it together again, and *regelation* immediately heals the fractures." By alternately crushing and squeezing a block of ice, it can be made to assume a variety of forms. Faraday applied the term *regelation* to the phenomenon witnessed when two pieces of damp ice are pressed together and they become welded.]

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* PARKES' *Practical Hygiene*, 7th Ed.

CHAPTER V.

RAIN-WATER AND RAINFALL.

445.—*What are the chief characters of rain-water?*

Rain-water is soft and well aerated, but its purity and fitness for drinking or even for washing purposes depend upon the purity of the atmosphere through which it falls. Near the coast it often contains traces of chlorides and sulphates, due to its sea-origin. It acquires from the air not only oxygen, nitrogen, carbonic acid and ammonia, with a minute amount of nitric acid, but also microbes and any organic or other impurities that may be present in the air. In land districts there is a marked increase in the sulphuric acid, ammonia, and organic matter, due to putrefactive processes and the combustion of coal. Near towns rain may become acid in reaction, from excess of sulphurous and sulphuric acids, and is liable to carry down considerable quantities of tarry and carbonaceous matter from the smoky air. Ammonia is found in largest proportion during the early part of a shower. A litre of rain contains about 25 c.c. of gases, namely, 8 c.c. of oxygen, 16·5 c.c. of nitrogen, and 0·5 c.c. of carbonic acid. Dew and snow-water have practically the same characters as rain-water, except that the dissolved gases are in less amount in snow-water.* Rain-water, of itself, is a pure water. When uncontaminated it is wholesome and pleasant to drink. In its passage through the air it becomes aërated, and if it remained in this simple natural state would be safe for drinking purposes. But in its descent, rain is liable to contamination from the substances which the atmosphere holds suspended, this action being specially observable in the neighbourhood of towns and of manufactories. Chemical impurities of various kinds such as sulphuric acid, ammonium salts, nitrous and nitric acids, particles of soot, etc., are thus liable to render it impure, while more serious contamination may result from the presence in the air of effete animal and vegetable products. Rain also carries down NaCl, $CaCO_3$, S, P, FeO, organic matter from various sources, debris of dust, etc. Hence rain-water in England is rarely stored or used, except for washing purposes, although in certain places it is necessary to store it for drinking purposes. The rain-water penetrating the strata of the land, forms springs flowing out at a lower level, gives rise to brooks, rivers, and lakes. The rain-water condensed from the ocean, is pure, soft, and does not contain mineral impurities. This soft water, however, is a powerful solvent, and on reaching the earth dissolves some and combines with other minerals with which in its onward progress it comes into contact, such as lime, magnesian salts, certain sulphates, chlorides, and a few gases.* Rain is a great purifier of air; for it washes out of it gaseous and solid impurities—organic and inorganic. For this reason also the rain which falls in the impure smoke and soot-laden atmosphere of large towns, is unfit to drink.

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* WHITELEGGE'S *Hygiene and Public Health* (Cassell & Co., London, 1890).

[As it falls through the air, rain becomes highly aërated (average, 25 cubic centimetres per litre), the oxygen being in larger proportion than in atmospheric air (32 per cent., or a little more); and carbon dioxide constitutes 2½ or 3 per cent. of the gas. It carries down from the air, ammonium salts (carbonate, nitrite, and nitrate), and nitrous and nitric acids in small amounts The total quantity of nitrogen in ammoniacal salts, nitrous and nitric acid, is ·0985 parts per 100,000. Frankland puts the average at ·032. At Montsouris, mean of seven years, the ammonia amounted to ·193 per 1,000,000, or ·0135 parts per gallon; the nitric acid (NO_3), mean of six years, to 354 per 100,000, or ·248 per gallon. This gives a total nitrogen, from ammonia and nitric acid, ·239 per 100,000. In towns with coal-fires it takes up sulphurous and sulphuric acids, and sometimes hydrogen sulphide. The sulphates in rain increase, according to Dr. Angus Smith, as we pass inland, and before large towns are reached; they are, according to this author, "the measure of the sewage in air" when the sulphur derived from the combustion of coal can be excluded, but in England the exclusion could never be made. Free acids are not found with certainty, according to Smith, when combustion and manufactures are not the cause. The acidity, taken as sulphuric anhydride was equal to ·0097 grains per gallon of rain in a country place in Scotland, and 1·0589 grains in Glasgow; in Manchester in 1870 it was ·8416, and in London, ·2713 grains.† See No 454.]

446.—*What is the purest natural water, and what does it usually contain?*

Rain or snow-water, if not contaminated in collecting. It contains little solid matter, except traces of ammonium nitrite and nitrate, but some oxygen, nitrogen, and carbon dioxide in solution.

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* AUTHOR'S *Hygiene of Water and Water-supplies.*

† PARKES' *Practical Hygiene*, 7th Ed.

447.—*What was the opinion of the Rivers Pollution Commissioners in regard to the quality of rain-water?*

They found that out of eight samples of stored rain-water only one was fit to drink. They came to the conclusion that rain-water collected from the roofs of houses and stored in underground tanks, is "often polluted to a dangerous extent by excrementitious matters, and is rarely of sufficiently good quality to be used for domestic purposes with safety." Also, that, "in Great Britain, and more particularly in England, we shall look in vain to the atmosphere for a supply of water pure enough for dietetic purposes."

448.—*How much air, oxygen* and CO_2 *does rain-water contain?*

Air about 25 c.c. per litre.
O ....32 per cent.
CO_2 ... ..2·5 per cent.

449.—*What is the ultimate source of all water?*

All natural waters are ultimately derived from the rainfall, which in its turn is due to distillation under the influence of the sun's rays from all humid portions of the earth's surface. Part of the rainfall is again evaporated from the surface upon which it falls, part flows along the surface to form streams and lakes. A third part sinks into the soil, descending vertically or obliquely through fissures or pores, until it reaches an impervious formation, and then either finds its way laterally to the surface in the form of springs, or accumulates in the porous strata overlying the impervious layer, where it may be reached by wells.*

450.—*What is the essential cause of rain-formation?*

Rain is owing to the cooling of a saturated air, and rain is heaviest under the following conditions—when, the temperature being high, and the amount of vapour large, the hot and moist air soon encounters a cold air. These conditions are chiefly met with in the tropics, when the hot air, saturated with vapour, impinges on a chain of lofty hills over which the air is cold. The fall may be 130 to 160 inches, as on the Malabar coast of India, or 180 to 220 as in Southern Burmah, or 600 as at Cherrapunji, in the Khasyah Hills. Even in England the hot air from the Gulf Stream impinging on the Cumberland Hills causes, in some districts, a fall of 80, 100, 200, and even more inches in the year. From any table of the weight of vapour it may be seen that the amount of vapour which can be rendered insensible, increases with the temperature, but not regularly; more, comparatively, is taken up by the high temperatures; thus, at 40°F., 2·86 grains are supported; at 50°, 4·10 grains, or 1·24 grains more; at 60°, 5·77 grains, or 1·67 grains more than at 50°. Therefore, if two currents of air of unequal temperatures, but equally saturated with moisture, meet in equal volume, the temperature will be the mean of the two, but the amount of vapour which will be kept invisible is less than the mean, and some vapour therefore necessarily falls as fog or rain. Thus one saturated current being at 40°F., and the other at 60°, the resultant temperature will be 50°, but the amount of invisible vapour will not be the mean. viz., 4·315, but 4·1; an amount equal to 215 will therefore be deposited.*

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* WHITELEGGE's *Hygiene and Public Health.*

451.—*Explain the causes of the formation of rain-drops and of their varying size.*

The meeting of cloud masses of varying temperatures and slight electrification seems to produce that coalescence of the minute "water dust" or moist particles, which we know as rain. As the rain-drops fall, under the influence of gravitation, they overtake one another and so increase in size according to the height from which they come. In thunder storms, and at the beginning and end of a shower, the drops are largest.

452.—*Is the composition of rain-water constant? What are rities under different circumstances and its general characters?*

Rain-water varies in composition according as it is collected in the country or in towns, but is never pure water. It invariably contains, besides the gases of the atmosphere, nitrates and nitrite of ammonium, solid amorphous and crystalline particles in suspension, and minute organisms. That of towns contains the acids generated by the combustion of coal, and notably sulphuric and hydrochloric acids. The aggregate amount of these two acids, in the free state, may reach as much as seven grains per gallon or ten parts per 100,000. Rain-water collected near the sea, and even many miles inland, contains small quantities of the salts present in sea-water. Even the rain-water collected in Florence was found by Bechi to contain 0·28 grain per gallon, or 0·4 part per 100,000 of solid matter, about half of which was organic, and half inorganic, the chief portion of the latter being sulphate of calcium and chloride of sodium. Bechi also determined the amount of ammonia and of nitric acid in the rain-water falling respectively in Florence, and at Vallombrosa. The ammonia was, on the average, 0·036 grain per gallon, or 0·51 part per million. In Vallombrosa the nitric acid was 0·041 grain per gallon, or 0·58 part per million, and in Florence 0·083 grain per gallon or 1·18 part per million. Lawes and Gilbert found the average aggregate amount of combined nitrogen in country rain-water, as ammonia, nitrates, and nitrites, to be nearly 0·07 grain per gallon, or one part per million. (See No. 447.)

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* PARKES' *Practical Hygiene*, 7th Ed.

453.—*What gases are contained in rain-water?*

Rain-water dissolves at the ordinary temperature of our country about 20 c.c. per litre, or 5·5 cub. inches per gallon, of the atmospheric gases, of which about 7 c.c. per litre, or nearly 2 cub. inches per gallon, are oxygen; 12·5 c.c. per litre, or 3·5 cub. inches per gallon, are nitrogen; and 0·5 c.c. per litre, or 0·14 cub. inch per gallon, is carbon dioxide gas. But rain-water is rarely, if ever, fully saturated with oxygen, this gas being in part appropriated by the organic matters present in the water; so that the oxygen rarely exceeds 1·75 cub. inches per gallon, or 6·3 c.c. per litre.

454.—*What are the results of the analyses of the Rivers Pollution Commissioners in their Sixth Report*[*] *as regards the gaseous constituents of rain-water?*

	Cubic inches, per gal.	c. c. per litre.
Nitrogen	3·63	13·08
Oxygen	1·77	6·37
Carbonic acid	0·35	1·28

455.—*What is the average composition of rain-water as regards saline constituents and combined nitrogen collected in inland districts remote from towns?*

	Grains, per gal.	**Parts,** per 100,000.
Saline constituents	2·11	3·0
Combined nitrogen	0·07	0·1

456.—*What is meant by rainfall, and how is it determined?*

By the term rainfall is meant the amount of rain that falls in a given time, generally a year. In all English-speaking countries it is calculated in inches. London, for example, has a rainfall of about 24 inches, the rain falling in London in an average year; which means that if none were lost by evaporation, soakage, or draining of the soil, the rainfall would cover the surface with a layer of water 24 inches deep. An inch of rain represents about 100 tons of water to the acre or 64,000 tons to the square mile. Rain is collected in a vessel called a rain-gauge, with a funnel-shaped mouth of known area, and the amount carefully measured at intervals usually once or twice a day.

457.—*How is rain-water and snow disposed of on reaching the earth?*

The water which falls from the clouds in the form of rain and is disposed of in three different ways. A certain portion runs off the surface and finds its way directly into the streams and rivers; another portion is taken up by vegetation, or lost by evaporation; and a third portion sinks into the earth, and forms the underground sheets of water which feed the springs that are met with in nearly every part of the world. It is stated that about one-third of the rainfall flows off the surface, one-third is taken up by vegetation or evaporation, and the remaining third sinks into the earth; but this can hardly be called even an approximation to the truth, as the proportions differ enormously in different cases, and at different seasons of the year. In a hilly and mountainous country much more water will evidently flow off the surface, and much less be evaporated, than in a flat country. In a district consisting chiefly of retentive clay, hardly any of the rainfall will sink into the ground, whereas in a district composed of permeable gravel or sand a very large proportion of the rainfall may be absorbed by the subsoil. In tropical climates evaporation will be much greater than in cold climates, and even in the same country evaporation will be much greater in summer than in winter. The relative amounts of rainfall disposed of in these ways vary with the configuration and density of the ground and with the circumstances impeding or favouring evaporation, such as temperature, movement of air, etc.

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[*] Issued in 1874.

458.—*Enumerate the methods by which the rain is disposed of on reaching the surface of the earth?*

1. Part flows away towards the natural channels;
2. Part is evaporated;
3. Part soaks into the soil;
4. Part is used in the support of animal and vegetable life on the surface and in the soil.

459.—*What proportions of rain-water sink into the soil in various districts?*

It varies considerably as stated in No. 459. Thus, in loose, tertiary, sandy or gravelly districts, as much as from 90 to 96 per cent. sinks into the soil; in chalk districts, 42; in sandstone, 20—25 per cent.; in magnesian limestone, about 20; in new red sandstone (Triassie), about 25 per cent., whilst in districts of retentive, impermeable clay, the percentage is very small. These may be again enumerated in tabular form for convenience.

Loose, tertiary sand absorbs	90 to 96	per cent.	of water.
Chalk	42	„	„
Sandstone	20—25	„	„
Limestone	20	„	„
Stiff clays	a very small proportion.		

In gravels and sands almost all percolates, in other soils more vaporates than percolates. Part of that which percolates is used up in the formation of hydraulic salts, part is absorbed by rootlets of vegetation and lost again by evaporation from leaves.

That which percolates finds its way beneath the soil and may crop out as springs at natural outlets or be rendered available by artificial tappings in their subterranean depths through borings, wells, etc. [Dr. Dalton, in his experiments on the new red sandstone soil of Manchester, found that 25 per cent. of the whole rainfall penetrated to the depth of 3 feet; and Mr. Prestwich gave the amount of infiltration of the principal water-bearing strata surrounding London as varying from 48 to 60 per cent.]

If, however, the inclination of the surface is great and the soil is not porous, but more or less impermeable to water, the greater portion of the unevaporated rain flows down the incline. It is this portion which forms or helps to swell the brooks, streams, and rivers, which are the natural drainage channels of the locality.

In very porous soils such as pure sand or coarse gravel, the rain so rapidly sinks into the interstices of the soil, that the evaporation even in summer is but slight. In nearly all other soils, however, the amount of rain evaporated greatly exceeds the percolation even in winter. There is always a certain amount of percolation in the summer months, and this varies within rather wide limits. In some years it is *nil*, in other years—as in 1879—it is as great as the evaporation (over 12 inches).

460.—*Does all the percolated water sink into the subsoil and subterranean lake?*

It does not; the portion that percolates, after a certain deduction that must be made for the moisture absorbed by the roots of vegetables and grasses growing on the surface, which is subsequently evaporated from their green leaves, helps to form and renew the underground sources of water.

461.—*Is the infiltration greater or less in an undulating country than in open level plains?*

Other things being equal, the amount of infiltration will be far less in an undulating hilly district than in open level plains. [It is obvious also that it must vary very considerably with the season of the year. Thus, according to the experiments of Mr. Dickinson, made in the gravelly loam which covers the chalk in the valleys around Watford, it was 70 per cent. in the first three months of the year; in the summer months it was only 2; while in November and December nearly the whole of the rainfall penetrated beneath the surface.]

462.—*Make some general remarks on the porosity of the various earths and rocks.*

Respecting the porosity and absorptive qualities of different earths, it may be observed that clean silicious sand, when thrown loosely together, has voids between its particles equal to nearly one-third its volume of cubical measure; that is, if a tank of one cubic yard capacity is filled with quartzoid sand, then from thirty to thirty-five per cent. of a cubic yard of water can be poured into the tank with the sand without overflowing. Gravel, consisting of small water-worn stones or pebbles intermixed with grains of sand, has, ordinarily, 20 to 25 per cent. of voids.

Marl, consisting of limestone grains, clays, and silicious sands, has from 10 to 20 per cent. of voids, according to the proportions and thoroughness of admixture of its constituents.

Pure clays have innumerable interstices, not easily measured, but capable of absorbing, after thorough drying, from 15 per cent. to an equal volume of water. The water contained in clays is so fully subject to laws of molecular attraction, owing to the minuteness of the individual interstices, that great pressure is required to give it an appreciable flow. Water flows with some degree of freedom through sandstones, limestones, and chalks, according to their textures, and they are capable of absorbing from 10 to 20 per cent. of their equal volumes of water. The primary and secondary formations, according to geological classification, as for instance, granites, trappeans, gneisses, mica-slates, and argillacious schists, are classed as impervious rocks, as are, usually, the several strata of pure clays that have been subjected to great superincumbent weight.

The crevices in the impervious rocks, resulting from rupture, may, however, gather and lead away, as natural drains, large volumes of the water of percolation.

The free flow of the percolating water toward wells or spring, is limited and controlled, not only by the porosity of the strata which it enters, but also by their inclination, curvature, and continuous extent, and by the imperviousness of the underlying stratum or plutonic rock.

463.—*What circumstances affect the proportion of rainfall disposed of in these different ways?*

The amount of rain that evaporates depends upon the temperature and degree of humidity of the air,—the higher the temperature and the drier the air, the greater the evaporation. When the inclination of the surface is but slight and the soil very permeable, a large part of the rain sinks into the earth; but if the soil is not porous, the greater part of the unevaporated water flows down the incline. This is the portion that helps to swell streams and rivers. A small share of the percolated rain-water is absorbed by the roots of trees, vegetables and grasses, but most of this is subsequently evaporated from green leaves When it rains heavily, the greater part of the water finds its way to the large rivers, and finally into the seas and oceans once more, after subserving the great offices in supporting animal and vegetable life.

464.—*What proportion of the rainfall is absorbed by the soil in England?*

The average for the year is about 42 per cent. [Winter 33 per cent.; spring 35; summer 2; and autumn 48 per cent.]

465.—*Upon what does the amount of evaporation depend?*

Upon (1) the temperature of the earth and (2) its degree of humidity. The higher the temperature the greater the evaporation. More evaporates in a dry than in a rainy season. *The amount of vapour rising from the tropical seas is enormous.* [Take merely 60 inches as the annual distillation and reckon this in feet instead of inches, and then proceed to calculate the weight of the water rising annually from such a comparatively small space as the Bay of Bengal, the amount is almost incredible.]

466.—*How much of the rainfall is lost by evaporation and percolation in England?*

In England the quantity varies from ½ to ⅞ths, varying with the season of the year and the porosity of the soil.

This is well shown in the following table.

Winter.			Summer.			Entire year.		
Rain.	Percolation.	Difference or loss.	Rain.	Percolation.	Difference or loss.	Rain.	Percolation.	Difference or loss.
13·33	8·11	5·22	14·09	2·18	11·91	27·42	10·29	17·13

467.—*Is there any relation between the amount of rainfall and the loss by evaporation and percolation?*

There is; the loss is great in proportion as the rainfall is small, and the loss is small in proportion as the rainfall is great.

468.—*How may we calculate the speed of evaporation?*

A shallow vessel of known area, protected round the rim by wire to prevent birds from drinking, is filled with a known quantity of water, and then, weekly or monthly, the diminution of the water is determined, the amount added by rain, as shown by the rain-guage, being of course allowed for. [In this little experiment it is advisable not to use a metal vessel which conducts heat so rapidly that in warm weather, at least, its own heat would expedite evaporation.]

469.—*What regulates the amount of evaporation from moist surfaces?*

It is regulated by the temperature of the water, the temperature of the air, the humidity of the air, and the wind. It is more rapid from moist soil than from water; and deep-rooted crops, such as wheat, dry the soil to a greater depth than grass. No satisfactory instrument (*atmometer*) has been devised for measuring evaporation, owing to the difficulty of excluding rainfall while allowing free exposure. A rough estimate may be obtained by exposing a measured volume of water in an open dish of known area, and deducting from the final measurement the ascertained rainfall. Another plan is to shelter the atmometer from rain by a cover, but this necessarily lessens the evaporation. The mean annual evaporation per square inch of water-surface is said to be 20·6 inches, and in some years it exceeds the rainfall.

470—*What is meant by the " evaporation " of water ?*

As a gas or vapour, water is invisible, though on a hot day if we lie on the ground we can see that the vapour as it rises from the earth so interferes with the rays of light as to produce the well-known " shimmering " effect. This passage of water into the condition of invisible vapour is termed evaporation.

471.—*What conditions favour evaporation ?*

Evaporation is constantly going on, at all times, in all temperatures and practically from all parts of the earth's surface. Being greatly increased by heat it is more rapid in the day than in the night, in summer than in winter, and within the tropics than nearer to the poles. It occurs to a greater extent also over the ocean, over lakes, rivers, or other water surfaces, but not exclusively, for vapour rises also from the leaves of plants, from snow and ice, and from ground that is apparently quite dry. The effect of evaporation is seen not only in the drying up of puddles after rain where part of the water may soak into the ground, but in the similar drying up of water placed in a saucer in the open air. The amount of evaporation varies with the degree of heat already in the air and the force of the wind. [Every laundress knows the difference between a " good drying day," when there is but little moisture in the air and the clothes dry quickly, and a bad one; but as hot air has a great capacity for moisture—can hold more moisture, that is, without being saturated—than cold air, there is usually more moisture in the air in the summer, when it feels dry, than in winter. Evaporation is greatly helped by wind. Wind removing saturated air and bringing fresh drier air in contact with puddles or other surfaces of evaporation, dries them up quickly.]

472.—*Does evaporation go on at all temperatures ?*

It does; water evaporates at all temperatures, and the evaporation of solid water in the form of ice and snow is an obvious and familiar phenomenon. (The tension of water-vapour, or its tendency to evaporate at any given temperature, is a subject dealt with in the Part of this series devoted to " METEOROLOGY.") The relative saturation of

air with aqueous vapour is termed 'humidity' of the atmosphere and bears no direct relation to the quantity of aqueous vapour therein. In the British Isles the amount of aqueous vapour in the atmosphere ranges from 2 grains per cubic foot of air in winter to 12 grains in summer, or from one-third per cent. to 2 per cent. by weight.

473.—*What follows from this constant evaporation?*

Were it not for this unceasing process of distillation, our water-supplies would become so highly charged with impurities as to become unfitted for the maintenance of animal life.

474.—*Is there a limit to the amount of vapour taken up by air?*

Air at any one temperature will only take up a certain quantity of water in the invisible form, after which it becomes saturated.

475.—*What amount of vapour rises from each square inch of surface per annum in England?*

The amount of vapour annually rising from each square inch of water surface in England has been estimated at from 20 to 24 inches; in the tropical seas it has been estimated at from 80 to 130, or even more inches. In the Indian Ocean it has been estimated at as much as an inch in twenty-four hours, or 365 in the year, an almost incredible amount. No doubt, however, the quantity is very great even if it does not reach this high estimate

476.—*When does the respiratory moisture become physically manifest?*

In dry warm weather the moisture in our breath is invisible, but in the cold of winter or when the air is saturated after rain, it is at once condensed into a cloud of minute drops of liquid.

477.—*When is rain-water good as a source of supply?*

Rain-water when uncontaminated by the receiving surface or by air impurities, is healthy and pleasant. It carries down from the air ammoniacal salts, sodium chloride, calcium compounds, and traces of organic matter, the total amount of solids being between 2 and 3 grains per gallon.

478.—*What is the average fall in England?*

Thirty inches. [At Netley for the period of 23 years (1864-86) the average was 30·12 inches.]

479.—*What is the average mean rainfall of England and Wales?*

The average mean rainfall of England and Wales is 32 inches per annum.

480.—*Upon what does the rainfall in England depend? Name some places where we get maxima of rainfalls.*

The quantity of rain which falls in various countries is affected by local circumstances, and varies with the seasons. The heaviest mean annual rainfall in England is at Stye-in-Borrowdale, Cumberland, where it is 165 inches; and the heaviest at any place on the globe is on the Khasyah Hills, Bengal, where it is 600 inches.

481.—*Does the rainfall vary in the same place? Give examples*

It varies within very wide limits. Thus at Bombay the mean is 76, but in the year 1822 as much as 112 inches fell, while in 1824 only 34 inches fell.

482.—*What is the average and extremes of the rainfall in England? How much is lost by evaporation and percolation?*

The average annual rainfall in England is 30 inches, and varies from 22 to 140 inches. A quantity is lost by evaporation and by sinking into ground. This varies from one-half to seven-eighths, according to the season of the year and the porosity of the soil.

483.—*What is the average rainfall of London?*

Twenty-four inches.

484.—*What is the annual rainfall of Edinburgh, Glasgow, Dublin and Manchester?*

Edinburgh	24 in. per annum.
Glasgow	40 ,, ,,
Dublin	30 ,, ,,
Manchester	36 ,, ,,

485.—*What is the least annual rainfall recorded in England?*

Fifteen inches.

486.—*Is the rainfall a very variable meteorological phenomenon?*

Rainfall is probably of all atmospheric phenomena, the most uncertain both as regards frequency and the amount which falls in a given time. In many parts of the world rain rarely if ever falls, whilst in others it rains almost every day. The rainless regions of the earth, as they have been termed, are the coast of Peru, the great valleys of the rivers Columbia and Colorado in North America, the Latona in Africa, and the Desert of Gobi in Asia. In Chili and Patagonia, rain is constant. [In calculating the rainfall by means of the rain-guage, it has been found that less rain is collected if the gauge be high above the ground than if it be level with it. Professor Phillips found the rainfall at York for twelve months during the year 1833-34 to be 14·96 inches at 213 feet from the ground, 19·85 inches at 44 feet, and 25·71 inches on the ground.]

487.—*Give instances of varying quantities of rainfall and state what circumstances affect the amount of the rainfall.*

Rainfall in different regions of the earth varies considerably from zero, as in the Desert of Sahara and on the coast of Peru, to six hundred inches, as on the south-east slopes of the Himalayas, which are exposed to the moisture-laden monsoons. The circumstances on which the amount of rain depends are partly *general*, such as degree of latitude and elevation above sea-level; and partly *local*, as nearness of large surfaces of water, exposure to moist winds, adjacency to mountain chains. As to the distribution of rain according to latitude the amount decreases, as a rule, with the increasing distance from the equator towards the poles; but this rule has many exceptions, such as the rainless tracts already mentioned, and lesser deviations in the positive and negative direction The amount of rain which falls in different regions is not proportionate to the moisture of the air, for a region may be almost free from rain, in spite of a humid atmosphere, if there are no cold winds causing condensation, as is the case with Lima, on the coast of Peru; and, on the other hand, localities with considerable rainfalls may enjoy tolerable dryness of air and soil, as the Gulf of Genoa. Elevation above sea-level does not seem to exercise the same influence in different regions. Gasparin and others assume that with increasing elevation the amount of rainfall increases, and according to Chaix this is the case with the Swiss Alps, subject to certain exceptions; but no such rule holds good for America. The *neighbourhood of the sea* is, for the west of Europe and the islands belonging to it, a cause of increased rainfall.

488.—*Name some rainless places?*

Peru, Columbia, Colorado, Sahara Desert, Gobi Desert, Beluchistan, etc.

489.—*Name some very rainy places?*

Patagonia; certain places in India, as Mahbleshwar, along the Malabar Coast, Cherrapungi in the Khasyah Hills (where as much as 600 inches fall per annum!), in Lower Burmah, and in some parts of the Cumberland Hills.

490.—*How do you account for the comparatively heavy rainfall in the last mentioned place?*

By the fact of the warm and moist air of the Gulf Stream coming into contact with the cold air of the elevated land in Cumberland becoming condensed and falling as rain.

491.—*What is meant by Drainage-Basins?*

If we trace the rivers on a map from their mouths up to the spring or glaciers in which they have their origin, not only shall we be going steadily up hill, but we shall find it generally easy to draw a line on the map separating the district drained by one river and its tributaries from those drained by other neighbouring rivers. This line is the *water-shed* or *water-parting* between the *river basins* or *drainage* areas, or as it is called in the north of England, "the heaven water boundary." Though very often so, this line is not necessarily the summit of a range of hills, the ground in many cases being relatively high, the water easily finds the slopes, however small, and runs down it. In Ireland the basins of the Harrow, the Boyne, and the Brosna are separated by the comparatively low-lying tract known as the *Great Bog of Allen*. As we shall see later on, by the use of curved lines traversing the maps, or by various colours, we may indicate on special charts the distribution of temperature, rainfall, groups of plants or animals, races of men, or forms of religion, and just as the shades of one colour are often used to indicate a scale of height of temperature, of atmospheric pressure, or of rainfall, so they may be employed to show the greater or less density of population, *i.e.*, the numbers of human beings to the acre, or to the square mile (640 acres).

492.—*When are the factors of available amount of water and the rainfall of the catchment basin very important matters for consideration?*

When the water-supply of a town is collected from small streams or gathering grounds, the rainfall of the catchment basin and its available amount are items which ought to be carefully considered.

493.—*How may the available rainfall be readily calculated?*

The amount of water derivable from the rainfall in given cases is readily ascertained if the mean annual rainfall of the district is known and the dimensions of rain-receiving area are calculated.

494.—*More rain is said to fall near the ground than higher up, why is this?*

There is only an apparent greater fall near the ground. The wind causes the rain to fall obliquely and not perpendicularly, and if a vessel of known dimensions be inclined to the direction of the wind at some distance from the ground, it will receive as much rain as one of the same dimensions placed on the ground.

495.—*What is the real cause of the diminution of rainfall at a level higher than the ground?*

It has recently been proved that there is really no decrease of rainfall, but that the apparent diminution is due to the fact that a gauge placed in an exposed position above the ground does not collect all the rain that falls, a certain proportion being blown over the gauge by the wind.

496.—*Why is the rainfall greatest on the west slopes of English mountains?*

Because the humid westerly (or seaward) winds deposit moisture as soon as they are forced to ascend into colder strata of air.

497.—*What is a rain-gauge?*

A rain-gauge or *pluviometer* is an apparatus for measuring the quantity of rain falling on a particular spot.

498.—*How may we estimate the rainfall?*

By means of a rain-gauge. There are several forms of rain-gauges. The simplest consists of a funnel opening into a receiver in which the rain is collected, and from which it may be drawn and measured. The funnel should have a truly horizontal rim, else the gauge will catch too much or too little, according to the direction and force of the wind.

499.—*Describe the construction of an ordinary rain-gauge, and the precaution which should be taken in fixing it.*

An ordinary rain-gauge consists of a circular metal cylinder varying from 5 to 8 inches (5 inches being the better gauge) in diameter, which by means of an open funnel top discharges the rain caught within its area into a graduated glass measure, the graduation being to $\frac{1}{100}$dth of an inch. It should be fixed perfectly level, not less than 6, or more than 12. inches above ground, in an open space at some distance from buildings or tall shrubs, trees, etc., the least objectionable shelter being from E., N., and N.-W., but for an accurate register no such shelter should exist. It is requisite to take the record by emptying the measure at a fixed time, each day, usually 9 A.M., and to remember that $\frac{1}{12}$th the depth of snow is equivalent to rain.

500.—*Describe the rain-gauge used by the Army Medical Department in determining the rainfall of a Military Station.*

This rain-gauge is a cylindrical tin box with a rim or groove at the top; a circular top with a funnel inside fits on to this groove, which, when filled with water, forms a water-valve. The opening above is circular (the circle being made very carefully, and a rim being carried round it to prevent the rain-drops from being whirled by wind out of the mouth), and descends funnel-shaped, the small end of the funnel being turned up to prevent evaporation. But leaves, dust, or insects sometimes choke this tube, so that it is now generally straightened, the loss by evaporation being insignificant, compared with that caused by obstruction. The best size for the open top, or, in other words, the area of the receiving surface, is from 50 to 100 square inches. The lower part of the box is sunk in the ground nearly to the groove; the upper part is then put on, and a glass vessel is placed below the funnel to receive the water. At stated times (usually at 9 A.M. daily) the top is taken off, the glass vessel taken out, and the water measured in a glass vessel, graduated to hundretdhs of an inch, which is sent with the gauge.[*]

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[*] PARKES' *Practical Hygiene*, 7th Ed.

501.—*How is the rainfall expressed, and how is it calculated?*

Rainfall is estimated in inches; that is, the fall of an inch of rain implies that on any given area, say a square yard of surface, rain has fallen equal to one inch in depth. The amount of rain is determined by a rain-gauge. Two gauges are supplied for military stations; one to be placed on the ground, one 20 feet above it; in all parts of the world the latter indicates less rain than the lower placed gauge; this is due to wind.* (See Nos. 494, 495 and 508.)

502.—*What does each division of the measure correspond to?*

One-hundredth of an inch of rain.

503.—*If the rainfall is very heavy, in what way is it measured by the ordinary rain-gauge?*

If there is a considerable rainfall then the measure is filled each time up to the 50 and recorded thus:—

Suppose that there were 136 one hundredths of an inch—

·50
·50
·36

that is, the rainfall is one inch and thirty-six hundredths. The figures should be written down before the water is thrown away, and the additions should be gone over twice.

504.—*How is the rainfall recorded?*

By emptying the contents of the bottle into the glass measure, which should be held quite perpendicular, and reading the number of decimals to which the water rises.

Each division = $\frac{1}{100}$dth inch and is recorded thus: ·01, 50 hundredths is recorded as ·50.

505.—*How many observations should be made?*

One, under all ordinary circumstances, but with heavy rain two or more, as the bottle may overflow and with a dry air it should be recorded at once, as part of the water may evaporate.

506.—*In the case of a single observation what is the best time to register the rainfall?*

At 9 A.M.

507.—*At what level should the rain-gauge be placed?*

Some observers maintain that the rain-gauge should be placed *at least six inches* from the ground, to avoid splashing, and in the centre of a level, open plot; others, that the best location for it is to bury it in the earth, making its top just even with the surface of the ground (LOOMIS). The higher the gauge is placed above the surface of the earth the less rain it catches.

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* PARKES' *Practical Hygiene*, 7th Ed.

508.—*Are the indications of pluviometers (or rain-gauges) placed in high situations reliable?*

They are not; they register less rain than those placed on a level with the neighbouring ground. When there is a wind during a shower, the course of the rain-drops is parabolic, being much curved in the air above and nearly vertical at the surface of the ground. A circular rain-gauge held horizontally, presents to inclined drops an elliptic section, and consequently less effective to vertical drops.

509.—*What precautions are to be taken with regard to the position in which the rain-gauge is placed?*

A rain-gauge should not be set on a slope or terrace, but on a level piece of ground, at a distance from shrubs, trees, walls, and buildings—at the very least as much from their base as they are in height. Tall-growing flowers, vegetables and bushes must be kept away from the gauges. If a thoroughly clear site cannot be obtained, shelter is most desirable from E, N, and N.-W.; less so from S. S.-E. and W. and not at all from S. W. or N.-E.

510.—*What precautions are to be taken with regard to the places in which old rain-gauges are still in use?*

Old established gauges should not be moved nor their registration discontinued until at least two years after a new one has been in operation, otherwise the continuity of the register will be irreparably destroyed. Both the old and new ones must be registered at the same time and the results recorded for comparison.

511.—*What precautions are to be observed in regard to the level of site in which a rain-gauge is placed?*

The funnel of a rain-gauge must be set quite level, and so firmly fixed that it will remain so in spite of any gale or wind under ordinary circumstances. Its correctness in this respect should be tested from time to time.

512.—*What precaution is to be observed as regards the height at which a rain-gauge should be placed?*

The funnel of gauges newly placed should be one foot above ground.

513.—*How may the funnel be prevented from rusting?*

If the funnel of a japanned gauge becomes so oxidised as to retain the rain in its pores or threatens to become rusty, it should have a coat of gas tar or japan-black, or a fresh funnel of zinc or copper should be provided.

514.—*What precaution is to be observed in the use of float-gauges?*

If the measuring rod is detached from the float, it should never be left in the gauge; if it is attached to the float, it should be pegged or tied down, and only allowed to rise to its proper position at the time of reading To allow for the weight of the float and rod, these gauges are generally so graduated as to show zero only when a small amount of water is left. Care must always be taken to set the rod to the zero.

515.—*What special precaution is to be observed in the use of the can and bottle-gauge?*

The measuring glass should always be held upright. The reading is to be taken generally between the two apparent surfaces of the water.

516.—*At what times should rain-gauge readings be made?*

Nine A.M. daily; if taken only monthly, then 9 A.M. on 1st.

517.—*What special precaution is to be observed in regard to date of entry?*

The amount measured at 9 A.M. on any day is to be set against the previous one; because the amount registered at 9 A.M. of day 17th, contains the fall during fifteen hours of the 16th and only nine hours of the 17th. (This rule has been approved by the Meteorological Societies of England and Scotland, and cannot be altered, and is particularly commended to the notice of observers.

518.—*What is the mode of entry of the rainfall?*

If less than one-tenth (10) has fallen, the cipher must always be prefixed; thus, if the measure is full up to the seventh line it must be entered as ·07—that is, no inches, no tenths, and seven-hundredths. For the sake of clearness, it has been found necessary to lay down an invariable rule that there shall always be two figures to the right of the decimal point. If there be only one figure, as in the case of one-tenth of an inch (usually written ·1), a cipher must be added, making it ·10 Neglect of this rule causes much inconvenience. All columns should be cast *twice*—once up and once down, so as to avoid the same error being made twice. When there is no rain a line should be drawn rather than cipher inserted.

519.—*What sepcial point demands attention in regard to the registration of the rainfall?*

The amount should always be written down before the water is thrown away.

520.—*How are small quantities of rainfall to be recorded?*

The unit of measurement being ·01, observers whose gauges are sufficiently delicate to show less than that, are, if the amount is under ·005, to throw it away, if it is ·005 to ·010 inclusive, they are to enter it as ·01.

521.—*What arrangements should be made in case of unavoidable absence?*

Every observer should train some one as an assistant; but where this is not possible, instruction should be given that the gauge should be emptied at 9 A.M. on the 1st of the month, and the water bottled, labelled, and tightly corked, to await the observer's return.

522.—*What precautions should be made in case of heavy rains?*

When very heavy rains occur, it is desirable to measure immediately on their termination; and it will be found a safe plan, after measuring, to return the water to the gauge, so that the morning's registration will not be interfered with. Of course, if there is the slightest doubt as to the gauge holding all that falls, it must be emptied, the amount being *previously* written down.

523.—*How may the rainfall represented by snow be recorded?*

In regard to snow three methods may be adopted. It is well to try them all. (1) Melt what is caught in the funnel by adding to the snow a previously ascertained quantity of warm water and then deducting this quantity from the total measurement, enter the residue as rain. (2) Select a place where the snow has not drifted, invert the funnel, and turning it round, lift and melt what is enclosed. (3) Measure with a rule the average depth of snow, and take one-twelvth as the equivalent of water. Some observers use in snowy weather a cylinder of the same diameter as the rain-gauge and of same depth. If the wind is at all rough, all the snow is blown out of a flat-funnelled rain-gauge.

524.—*What precaution is to be observed to prevent overflow?*

It would seem needless to caution observers on this head, but as recent foreign tables contain *six instances* in one day in which gauges were allowed to run over, it is evidently necessary that British observers should be on the alert. It is not desirable to purchase any new gauge of which the capacity is less than that equal to 4 inches of rain.

525.—*If two gauges are in use how should the rainfall be registered?*

It is often desirable that observers should have two gauges, and that one of them should be capable of holding 8 inches of rain. One of the gauges should be registered daily, the other weekly or monthly as preferred, but always on the 1st of each month. By this means a thorough check is kept on accidental errors in the entries, which is not the case if *both* are read daily.

Small amounts of water are at times deposited in rain-gauges by fog and dew. They should be added to the amount of rainfall because (1) they "tend to water the earth and nourish the streams," and not for that reason only, but (2) because in many cases, the rain-gauges can only be visited monthly, and it would then obviously be impossible to separate the yield of snow, rain, etc.; for the sake of uniformity, all must be taken together.

526.—*By what rule may we find the depth of glass of a given diameter to contain one inch of water distributed over the area of a given gauge?*

First find the weight in ounces of one inch depth of rain-water in the rain gauge, thus.—Multiply the area of the rain-gauge in square inches by 252·458, and divide by 437·5. Then divide the weight of water in ounces by the product of the square of the diameter in inches of the glass by ·45317.

527.—*How may we ascertain the relation between a rain-gauge and its measuring glass?*

Determine the area in square inches of the receiving surface, or top of the gauge, by careful measurement. This area if covered with water to the height of 1 inch would give a corresponding amount of cubic inches. This number of cubic inches is the measure for that gauge of 1 inch, because when the rain equals that quantity, it shows that 1 inch of rain has fallen over the whole surface

Suppose the area of the receiving surface is 90 square inches. Take 90 cubic inches of water and put it into a glass, put a mark at the height of the fluid and divide the glass below it with 100 equal parts. If the rainfall comes up to the mark, 1 inch of rain has fallen on each square inch of surface; if it only comes up to a mark below, some amount less than an inch (which is so expressed) in $\frac{1}{10}$th and $\frac{1}{100}$dth has fallen.*

For example, suppose the diameters of rain-gauge and collecting glass be given, how may we find the depth of the glass to contain one inch of water collected by the gauge, the diameter of gauge being 7 inches, and the glass 3 inches.

$$7^2 \times 0{\cdot}7854 = 38{\cdot}4846 \text{ area of gauge.}$$

$$\frac{38{\cdot}4846 \times 252{\cdot}458}{437{\cdot}5} = 22{\cdot}205 \text{ oz. of water.}$$

Then

$$\frac{22{\cdot}205}{3^2 \times 0{\cdot}45317} = 5{\cdot}44 \text{ depth of glass required.}$$

0·45317=a constant which may also be used to find the weight of an inch of water intercepted by the gauge, by multiplying the square of the diameter by it.

528.—*By what rule can we find the weight of water in ounces per inch in depth, distributed over the area of the rain-gauge?*

Rule.—Multiply the square of the diameter in inches by the constant number ·45317.

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* PARKES' *Practical Hygiene*, 7th Ed.

529.—*If $\frac{1}{8}$th inch rain fall in 10 minutes how much would fall in 24 hours over a square mile of surface?*

$\frac{1}{8} \times 6 \times 24 = 18''$ in 24 hours
1 inch over 1 acre = 101 gallons
18 „ 1 „ = 101 × 18 = 1,818 gallons.
18 „ 640 „ = 1,818 × 640 = 1,163,520 gallons.

This may be also worked out as follows :—
$\frac{1}{8} \times 6 \times 24 = 18''$ in 24 hours = 1·5 feet
5280 (feet in a mile) squared
= 418,176,000 cubic feet in 24 hours.
418,176,000 × 6·2 (gallons in a cubic foot, approximate).
= 2,592,691,200 gallons for 24 hours.
2,592,691,200 × 10 (lbs. in a gallon) and ÷ by 2,240 (lbs. in a ton of water) = 11,574,514$\frac{2}{7}$ tons in 24 hours. (See No. 538.)

530.—*What amount of rainfall in a small water-shed flows through the outlet on a rocky surface?*

When the surface of a small water-shed is rocky or impervious or frozen, $\frac{2}{3}$rds of the rainfall may flow through the outlet channel.

531.—*What precaution is to be taken in measuring the rainfall when snow falls instead of rain?*

The snow must be melted and the water it represents measured. This may be carried out by the addition of a known quantity of hot water, the latter being deducted from the whole of the water measured.

532.—*What is meant by the annual rainfall of a place?*

By the amount of annual rainfall at a given place is meant the depth of water that would be obtained if all the rain which falls there in a year were collected into one horizontal sheet. The depth of rain that falls in any given shower is similarly reckoned. It is the depth of the pool which would be formed if the ground were perfectly horizontal, and none of the water could get away.

533. *How may we calculate the quantity of rain intercepted by a rain-gauge?*

Multiply the area of gauge by 252·458, divide product by 437·5; the result is the weight in ounces of one inch depth of rain over the area of the gauge.

252·458 = weight in grains of 1 cubic inch of water at 62° F.
437·5 = „ „ of 1 ounce avoirdupois.

$$w = \frac{a \times 252{\cdot}458}{437{\cdot}5}$$

w = water in ounces; a = area of gauge ($D^2 \times 0{\cdot}7854$).

534.—*In what description of places does rainfall reach its maximum?*

Mountainous districts (particularly on the leeward side of mountains); and in districts which face the prevailing winds. As an example we have the warm air of the Gulf Stream saturated with moisture impinging on the Cumberland Hills causing a considerable rainfall in some districts; the Western Ghauts in India similarly related to the South-West winds from the Indian Ocean. The greater the temperature of the air the more water it is capable of holding in the form of suspended vapour. When the warm air comes into contact with cold mountain side its temperature is suddenly reduced, and as a result so much of the suspended vapour which at the higher temperature it held in the air, is deposited. One side of a high mountain may be very fertile, whilst the other is practically a desert; as is seen in the Desert of Gobi which is caused by the Himalaya mountains.

535.—*How may we explain this increased rainfall in certain districts?*

The atmosphere is capable of holding a certain amount of water in the vaporous state, its capacity in this respect varying with the temperature—the greater the temperature of the air the larger the quantity of watery vapour it can hold in suspension. Currents of *warm* air laden with vapour impinging upon cold mountains has its capacity for holding watery vapour reduced by reason of the lowered temperature. the result is that some of the vapour is condensed in the form of rain. This explains the anomaly that one side of a mountain range may be fertile and the other an absolute desert.

In England the hot air from the Gulf Stream impinging on the Cumberland Hills causes, in some districts, a fall of 80, 100, 200, and even more inches in the year.

The rainfall in different places is remarkably irregular from year to year; thus at Bombay the mean being 76. in 1822 no less than 112 inches, while in 1824 only 34 inches, fell.

In districts having an average rainfall (25 to 30 inches per annum). the amounts of rain that fall in summer and in winter are very nearly equal. But in the summer months (April to September) the amount of rain that percolates is very small; it is only one-seventh of the summer rainfall in chalky soils. Nearly all the rain that falls in an average summer is evaporated from the surface of the soil or from the leaves of plants. The consequence is that the underground-water is not replenished from the surface, and its level sinks. In the winter months (October to March) considerably more than half the rainfall percolates.

536.—*What are the limits of variation of rainfall in the United Kingdom?*

The annual rainfall varies from about 20 inches on the eas

coast of England to 60 or 80 inches on the west coast of Ireland and Scotland; and at one point in Cumberland (Seathwarte) it averaged 154 inches during 6 years.

The amount of yearly rainfall varies considerably in different parts of England. In the Eastern counties the average is less than 25 inches per annum; throughout the remainder of England the average is from 30 to 40 inches per annum, with very much larger amounts in the mountainous and hilly districts of Devonshire, Wales, Cumberland and Westmoreland (60 to 200 inches per annum).

537.—*What is the maximum rainfall in a day in Great Britain?*

The rainfall does not often exceed an inch in one day in Great Britain, but enormous quantities are recorded occasionally. At Camberwell, in 1846, 3 inches fell in 2½ hours, and in Monmouthshire, in 1875, 5·36 inches fell in one day

538 —*Calculate rainfall: if ⅛" fall in 10 minutes, what would be the amount in 24 hours over a mile? Show the working.*

$\frac{1}{8} \times 6 \times 24 = 18''$ in 24 hours $= 1·5$ feet.

5280 feet in mile—to be squared.

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   422400
  10560
 26400
 --------
 27878400
      1·5
 ---------
 139392000
 27878400
 ---------
 418176000
      6·2 gallons in a cubic foot of water.
 ---------
 836352000
2509056000
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2,592,691,200·0 gallons in 24 hours.*

539.—*What is considered to be a rainy day?*

One in which at least ·01 inch of rain falls.

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* See Answer to No 529

540.—*What are the more important factors influencing the ratio of the available to the total rainfall?*

The nature of the soil, and steepness or flatness of the ground, the rapidity of the rainfall, and other circumstances.

541.—*What are the causes that influence the amount of rainfall?*

1. *Latitude*.—The greatest rainfall is near the Equator, diminishing towards the Poles. But the number of rainy days at the Equator and at latitude 60° are very nearly the same.
2. *Elevation above the sea*—Mountains increase the rainfall.
3. *Proximity to the ocean*.—It is almost always raining on the west coast of Ireland and Britain. The Gulf Stream has much to do with this rainfall.
4. *Trees* increase the rainfall.
5. *Winds* do. do.
6. *Deserts*.—Almost entire absence of rain.

542.—*Why do forests increase the rainfall?*

In large forests the temperature is somewhat lower than it is in the surrounding areas. The result is that currents of air containing much moisture on reaching the area shrouded in trees, is condensed and falls as rain when it would not do so in the neighbouring areas. The forests lower the air temperature and if its dew point is reached water condenses as rain. The capacity of air to hold aqueous vapour in suspension is lessened as the atmospheric temperature decreases.

543.—*What are the objections to rain-water as a source of supply?*

(*a*) It is uncertain.
(*b*) The quantity falling in a given area is frequently inadequate for the requirements of the community.
(*c*) Its collection and storage are expensive.
(*d*) The stored water is very liable to contamination.
(*e*) Rain-water is somewhat insipid and vapid.*

There is one great disadvantage possessed by rain and other soft waters, namely, their liability to dissolve lead, iron, or zinc, if left in contact with these metals. Consequently cisterns of lead, iron, zinc, or galvanized iron should not be used to store rain-water; and such water when collected from lead roofs should not be used for drinking purposes.

544.—*What are the chief disadvantages of rain-water supply?*

Its scantiness and uncertainty. A rainfall of 25 inches per annum is equal to 2,523 tons per acre, or 565,380 gallons yearly, and even if this were all collected and stored without loss, it would suffice for 62 persons only, each person being allowed 25 gallons *per diem*. During times of drought when evaporation is usually great, it is manifest that a rain-water supply must be deficient, except where only a small number of persons has to be supplied.

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* HUSBAND'S *Forensic Medicine and Medical Police*.

545.—*Name some other disadvantages of rain-water?*

It is almost too soft to be pleasant to the palate, near the sea it contains some salt, and in towns, ammonia. Being soft and containing O, it dissolves lead.

546.—*What is the special disadvantage of rain and other soft waters?*

Their power of dissolving lead, iron, and zinc from pipes or cisterns.

547.—*Upon what does the quality of stored rain-water depend?*

1. The nature of the air through which it passes.

2. The cleanliness and purity of the channels through which it runs, and the condition of the cisterns or water-butts.

548.—*Under what conditions may it be used with advantage?*

1. Where existing springs are bad from impregnation with earthy salts, as in the "neutral ground" at Gibraltar, and in many Dutch towns.

2. It may also be used with advantage during outbreaks of cholera.

549.—*As regards quality are rain-waters good as a source of supply?*

Only at their sources in hills.

550.—*How does rain-water become contaminated?*

Rain-water may be contaminated by washing the air it falls through, but more so by matters on the surface on which it falls, such as decaying leaves, bird-droppings, soot, or other matter on the roofs of houses; it also takes lead from lead coatings and pipes, and zinc from zinc roofs. If stored in underground tanks it may also receive soakings from the soil through leakage.

551.—*What is the effect of the CO_2 of rain-water, after rain reaches the earth?*

CO_2 in rain-water that soaks the foul surface soils, gives the water power to carry down to the wells a superabundance of impurities.

552.—*For practical purposes what are the most important data respecting the depth of rainfall in a given district?*

1. The least annual rainfall.

2. The mean annual rainfall.

3. The greatest rainfall.

4. The distribution of the rainfall at different seasons, and especially the longest continuous drought.

5. The greatest flood rainfall, or continuous fall of rain in a short period.

In the question of water-supply, the least annual rainfall and the longest drought are the most important facts to ascertain.*

553.—*Which are the more important of these?*

The least annual rainfall and the longest period of drought.

554.—*What special points are to be considered as to rainfall?*

The mean maximum and minimum monthly rainfall, from which the mean and extreme falls for each natural local season, wet, cold, and hot, can be obtained. The mean and maximum daily falls in twenty-four hours, for each month, in the rainy reason. Or, mean and maximum hourly falls, longest continuous falls and droughts, and special occurrences.

These arranged in a convenient tabular form are all the rainfall data that the engineer will generally require.

555.—*What are the proportions of the least, mean, and greatest annual rainfall to one another?*

It may be stated as the result of experience, that the proportions of the least, mean, and greatest annual rainfall at a given station or place usually lie between those of the numbers 2, 3, and 4 and those of the numbers 4, 5, and 6.

556.—*What is the soundest basis upon which to calculate the supply in a given district?*

By taking the average of the three driest years, which will usually be about $\frac{5}{6}$ths the annual rainfall.

557.—*What is the relation between the greatest and least annual rainfall to the average rainfall?*

About one-third above, and one-third below, the average, respectively.

[For purposes of water-supply it is not sufficient to know the average rainfall, but we must know the extremes, namely, the rainfall of the wettest and driest years. From an examination of a great number of records of different places, it appears that the rainfall of the wettest year is generally rather more than double that of the driest year. If we assume the rainfall of the wettest year to be exactly double that of the driest, we obtain the following approximate rule, which is exceedingly useful in practice:—

The fall in the driest year will be one-third less than the mean fall.
„ „ wettest „ „ more „ „

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* HEHIR'S *Hygiene of Water and Water-supplies.*

For example, with an average rainfall of 24 inches, the rainfall in the driest year will be 16 inches, and for the wettest year 32 inches, making the wettest year just double the driest year.]

558.—*What is the best rule to adopt as regards the utilization of rainfall for a water-supply?*

The greatest is generally about one-third more, and the least one-third less than the average. A safe basis is to take the average of the three driest years; this will generally be about five-sixths of the average annual rainfall. The rainfall varies in amount often in places near together.

559.—*How may we estimate the rainfall as a source of water-supply?*

By taking the rainfall of the three consecutive driest years.

560.—*Are these data accurate? If not, how may they be supplemented?*

Such data as the above may be used in roughly estimating the probable available rainfall of a district, but a much more accurate and satisfactory method is to measure the actual discharge of the streams (if there be any) at the same time that the rain-gauge observations are made, and so to find the actual proportion of available to total rainfall.

In addition to the knowledge of the amount of rainfall which can be depended upon in dry years, there must be an intimate knowledge of the locality from which the water is to be taken, of the drainage-area which will contribute to the supply, of the thickness and character of the water-bearing stratum, and of the direction of the movement of the ground-water.

561.—*How may the foregoing data be obtained?*

To obtain these data with accuracy, the daily rainfall of a given district for a period of 20 years is necessary. But observations over such a prolonged period are rarely to be had. Under these circumstances, the most reliable records of rainfall in the nearest station are to be obtained and calculated from.

In cases where actual rainfall observations on the gathering ground have been made for a long series of years, or even where an approximation to this has been formed by comparison between newly established gauges on the ground itself and the old established gauges in the neighbourhood, a simple calculation may be made of the storage capacity required to meet a given demand. The question of how far such calculation will, with a reasonable margin, form a reliable basis for estimation of the storage capacity, will of course depend upon the actual rainfall observations being sufficiently extensive to represent, within fair limits, the variations which may yet occur. Supposing this to be the case, and moreover that observations have been made upon the proportion borne by the actual flow off the ground to the amount of rain falling—which proportion will of course rapidly diminish as the absolute amount of rain is less—there can be formed a table or diagram of the available supply, showing its several fluctuations. The demand with its fluctuations to be provided for, will be known already, and it may be shown upon the diagram or inserted in the table. Then, working backwards in point of time, and taking the difference between the inflow and the draught, we may determine, by a simple process of addition and subtraction, what quantity will be required in store at the commencement of the several short periods—generally months—into which the time is divided. The maximum attained will be the net capacity of the reservoir, beyond which a margin of safety must be allowed, depending upon the considerations already referred to. The storage capacity thus determined will be equal to the demand for a certain number of days, which number will be greater as the mean annual demand is greater in proportion to the mean annual supply, and it will also be found greater as the mean annual fall is less.

The gathering ground having been determined, and its area ascertained, an estimate has to be formed of the available rainfall upon that area. The available fall is a quantity more or less short of the mean fall—how much so remains to be seen. The mean rainfall is determined by rain-gauges (some varieties of which have already been described in a former chapter). The first deduction from the mean annual fall is one rendered necessary by the variations in the amount of fall. The extent of these variations, as already stated, is found to be about two-thirds of the mean fall—that is, one-third in excess and one-third in deficit. Were the whole of the rainfall (neglecting for a moment the loss by evaporation) to be impounded, and an uniform quantity, equal to the mean fall, to be discharged from the reservoir, the storage capacity of the reservoir would have to be far greater in proportion to the supply than has hitherto been found economical. The greater the mean supply (rainfall) compared with the mean demand, the less will be the storage capacity required to ensure the demand being regularly met; and it is now the practice to consider as available no more than the mean fall for three consecutive dry years, and to secure a gathering ground correspondingly large. Where an extension of catchment area presents difficulties, and an increase of storage capacity unusual facilities, a modification of this practice may be advantageous. The mean fall in three consecutive dry years is found to be, with remarkable regularity, one-sixth less than the mean fall, and this deduction is therefore always made; the one-sixth passes away in floods which the reservoir is not large enough to impound.

562.—*Give a formula for obtaining the actual rainfall.*

Let F, the actual downpour in 24 hours, be 0·8 feet, and the loss by absorption and evaporation one-fourth; then the effective rainfall is:—

$f = 0{\cdot}8 - 0{\cdot}2 = 0{\cdot}6$, and the corresponding flood discharge per second Q, from a catchment (R) of four square leagues will be

$$Q = \frac{0{\cdot}6 \times 4\ (10{,}000)^2}{24 \times 60 \times 60} = 2{,}778 \text{ cubic feet per second.}$$

If the rainfall or the loss vary over portions of the catchment area, the parts may be treated in the same way, to obtain a total value of Q through summation. For this purpose the tables found in most works on Meteorology can be used.

563.—*In a given district or country what special conditions affect the amount of rainfall in different parts of that district?*

The rainfall in different parts of a given country is, in general, greatest in those districts which lie towards the quarter from which the prevailing winds blow; in Great Britain, for instance, the Western districts have the most rain. Upon a given mountain ridge, however, the reverse is the case, the greatest rainfall taking place on that side which lies to leeward, as regards the prevailing winds. To the same cause may be ascribed the fact that the rainfall is greater in mountainous than in flat districts; and greater at points near high mountain summits than at points farther from them; and the difference due to elevation is often greater by far than that due to 100 miles geographical distance.

564.—*What is meant by the available rainfall?*

The *available* rainfall of a district is that part of the total rainfall which remains to be stored in reservoirs, or carried away by the streams after deducting the loss through evaporation, through absorption by plants, by the ground, etc.

565.—*What is the proportion borne by the available to the total rainfall?*

The proportion borne by the available to the total rainfall varies very much, being affected by the rapidity of the rainfall and the compactness or porosity of the soil, the steepness, or flatness of the ground, the nature and quantity of the vegetation upon it, the temperature and moisture of the air, the existence of artificial drains, and other circumstances.

The following are examples:—

Nature of Ground.	*Available Rainfall.*
Steep surfaces of granite, gneiss, and slate, nearly	**1**
Moorland and hilly pasture...	**from ·8 to ·6**
Flat cultivated country	**from ·5 to ·4**
Chalk	**0**

Deep-seated springs and wells give from ·3 to ·4 of total rainfall.

[Such data as the above may be used in roughly estimating the probable available rainfall of a district; but a much more accurate and satisfactory method is to measure the actual discharge of the streams at the same time that the rain-gauge observations are made, and so to find the actual proportion of available to total rainfall.]

566.—*What is the usual hardness of rain-water?*

About half a degree; in other words there is in rain-water salts or acid equivalent to ½ grain of carbonate of lime to the gallon.

567.—*How may we represent this amount of hardness of the water?*

By stating that 1 grain of $CaCo_3$ wastes about 8 grains of soap.

568.—*What is the peculiarity about the rain-water collected in the first showers in a manufacturing town?*

It contains a very large quantity of sulphuric acid and is charged with a considerable amount of suspended matter. Sulphurous and sulphuric acids also appear to be less rapidly removed, as Angus Smith found a perceptible quantity in the air of Manchester; and the rain-water is often made acid and is liable to carry down considerable quantities of tarry and carbonaceous matter from the smoky air. Ammonia is found in largest proportion during the early part of a shower. A litre of rain contains about 25c.c. of gases, namely, 8c.c. of oxygen, 16·5c.c. of nitrogen, and 0·5c.c. of carbonic acid. Dew and snow-water have practically the same characters as rain-water, except that the dissolved gases are in less amount in snow-water.

569.—*What is there peculiar about the sulphates contained in rain-water?*

The quantity of sulphates contained in rain-water increases as we pass inland, and could we exclude the S of coal fires, the sulphates would be a measure of the "sewage of the air" (ANGUS SMITH).

570.—*What is the legal limit of rainfall that must flow into rivers?*

One-third.

571.—*What is the amount of the rainfall available for storage?*

It varies very considerably, but on an average about $\frac{4}{10}$ths is available.

572.—*Are there any towns or cities entirely or almost entirely supplied by rain-water?*

Yes: Constantinople, Malta, Gibraltar, Venice, certain towns in Holland and parts of South Africa.

573.—*Why are these places obliged to use collected rain-water?*

Because (1) they are below the sea-level or the level of the rivers, as a result of which sewage, etc., cannot be drained off and in many places contaminate the soil to such an extent that wells sunk in the soil supplies an unwholesome water; and (2), they have no springs fit to drink.

574.—*Is rain-water good as a source of supply?*

If collected on a prepared ground, it may be good on account of its purity, but it is at best an uncertain source of supply; it is very liable to be contaminated in the large storage reservoirs that are necessary to keep it in.

575.—*Is rain-water collected for domestic use?*

It is; in the country, and in certain towns where the air is free from smoke. the rain falling upon the roofs is collected and stored in cisterns for domestic use. It may, however, be collected from any other natural or artificial impervious surface. Its softness renders it valuable for washing. especially if the alternative supply is hard, but owing to sooty and other matters acquired from the air and from the roofs themselves, it is seldom obtained in a state of sufficient purity for drinking purposes. It has been estimated that on the average only about two gallons per head *per diem* could be collected in this way. The annual yield is found by multiplying the inches of annual rainfall by the square inches of sectional area of the building (not the slant surface of the roof). This gives the cubic inches of water per annum, and multiplied by 0·0036, the number of gallons. If rain is relied upon for more than auxiliary supply, the collecting surface and storage capacity must be regulated by the minimum annual rainfall and the longest dry season.

576.—*Compare rain-water with spring and well-water.*

River-water is softer than spring and well-water, and usually contains less mineral matter, but its composition is very complex, and varies with season—*e.g.*, summer or winter; it may also be contaminated with sewage, but as a rule river-water is fairly pure. Some springs and wells contain so much saline ingredients that they are only used for medicinal purposes, and are known as "mineral waters."

577.—*Explain, with reference to population, the subjects of gathering ground, rainfall and storage.*

The number of people to be supplied and the number of gallons per head required being known, area of gathering ground required will depend on the following factors. The mean annual rainfall, that is, the mean fall in the driest three consecutive years on record, must be ascertained; this will generally be about five-sixths of the average annual rainfall. A portion of the rainfall will be lost by evaporation and absorption. This will be much the same year by year, whatever the total fall, and may be equal to a fall of 10 to 14 inches, the total fall (in England) ranging from 16 to 70 inches, with a mean of 30. (There are one or two exceptional places where the fall is greater.) A further deduction from available rainfall capable of being stored will have to be made on account of storage to compensate mill-owners and others having water rights, perhaps to the extent of one-third or one-fourth of available total.

Capacity of storage reservoirs will depend upon area of catchment. With a catchment area large in proportion to population, and with a fairly distributed rainfall, the necessary storage space will be less than in a district where there are long droughts to be provided for, and where the catchment area being small it is essential that loss by escape of water during heavy floods should be minimized by providing large reservoirs.

Average loss by overflow of storm-water may be taken at about 10 per cent. of total fall. Average proportion of rainfall available for storage may be estimated at about six-tenths of the whole.

Reservoirs in rainy districts may contain 120 days' supply; in drier districts 200 days' supply.

Hawksley's formula for storage is $D = \frac{1000}{F}$.

D being number of days' supply to be stored, and F the mean annual rainfall (five-sixths of average). Storage capacity may vary from 25,000, to 50,000 cubic feet per acre of catchment area.

578.—*Does rain-water contain any bacteroid forms?*

It does; the rain washes out of the air countless bacterial and fungoid organisms and their spores. The rain which first falls in a shower, and that which falls after a period of dry weather, contain far larger numbers of bacteria than that which falls later on in a storm or succeeds the first shower: 200,000 germs per litre is not an unusual quantity under the first set of circumstances. During the warm months of the year, the number of bacteria in the rain are greatly in excess of those found in rain falling in winter and early spring. The greater number of the organisms in rain are micrococci. All the organisms (micrococci, bacilli, bacteria) found in rain exist to a larger extent in the form of germs or spores than in the adult state. Besides bacteria, pollen of grasses and flowers, microscopic plants such as the *protococcus pluvialis*, and spores of fungi are found in rain; the latter being sometimes in sufficient quantity to cause a localised fall of what is known as "coloured rain."

579.—*How is the rainfall of urban districts rendered impure?*

By acting as a scavenger of the air and soil, it washes the air of the streets, court yards, roofs, etc., and thus conveys away an immense amount of impurity.

580.—*In what manner does the rainfall affect the temperature of the soil and atmosphere?*

During its evaporation one grain of water absorbs as much heat as is sufficient to raise 960 grains of water to 1° F. The reason is that in its conversion into vapour water renders latent a considerable amount of heat. Soil that is well drained is *cæteris paribus* warmer than one not drained, because there is less water to evaporate.

581.—*How may rainfall be collected in an area?*

By rendering the surface impermeable by a covering of slates, asphalte or cement having sloped beds with outlets leading to a reservoir.

582.—*How may the water collected from a gathering ground be obtained and kept pure?*

The collection of drinking water from the surface of land needs, in the first place, a clean, uncultivated and uninhabited tract of land as a catchment area, and in the second place, the water stored in the reservoir, which is liable to become putrescent or seriously affected by the organisms, plants, and animalculæ that inhabit stagnant water, requires very perfect and careful filtration.

583—*To what special points should attention be given in the construction of under ground tanks?*

To see that they are water-tight; that they are properly covered, and thoroughly ventilated; to have them deep rather than broad; to keep the water cool and prevent evaporation; and to have them periodically cleaned out. The walls may be made of stone masonry, slate, etc., but in the former case hydraulic mortar and not ordinary mortar is to be used in the jointing. [Ordinary mortar yields lime to the water and makes it "hard." If the tank is large the roof should be supported on buttresses or piers.]

584.—*What special precaution is to be taken after collection?*

If rain-water is to be used for drinking purposes, it should always after collection be filtered through sand and charcoal, or other equivalent material, so as to remove suspended matter before storage; and it should then be kept for some time in carefully-covered and well-aired tanks or cisterns, lined with slate or other impervious non-metallic material. A good plan is to pass the water from a Roberts' separator through a conduit sufficiently wide to considerably diminish the velocity of the current, and over a catch-pit which will retain the grosser suspended particles. The conduit should then make a considerable dip, so as to deliver the water at the bottom of the filter, though it should pass in an upward direction to an effluent pipe conveying the filtered water into a covered slate-lined tank. The filter may consist of successive layers of coarse sand, charcoal, magnetic carbide, or other equivalent purifying material; coarse gravel, and sand.

585. —*What are the effects of rain-water on iron storage tanks and iron pipes connected with them?*

When iron tanks and pipes are used for the storage and distribution of rain-water, the metal becomes rapidly corroded; and no useful purpose appears to be served by coating the iron with zinc (galvanising); for the zinc is quickly removed, and the water becomes turbid with zinc compounds, and even contains this metal in solution. This zinc-caused turbidity persists until all the coating of zinc has been removed.

586.—*How are the under-ground cisterns prepared in Venice?*

An excavation is made in the soil as deep as practicable, generally about ten feet, and a brick floor and walls are built with a backing of puddled clay, so as to be water-tight. The walls are sometimes vertical, and sometimes they slope outward. A well-hole is built of brick, water-tight except at the bottom, where openings are left. The cistern is then filled with sand, and drains are constructed to collect and distribute the rain-water which runs from the houses and falls upon the streets and courtyards. The water is thus subjected to filtration through sand, and, as there are no draught-animals in Venice, the street-wash is not as bad as it would be in other places.

587.—*What precautions should be taken in the construction of tanks and wells when the ground is porous?*

When the ground is porous the brick lining should be of radiated bricks, with close vertical joints, and backed with puddled clay, 8 or 9 inches in thickness. Instead of clay a common kind of asphalte may be used, composed of gas tar and any non-porous dry material screened through $\frac{1}{8}$th inch meshes, and worked as for dry cesspits, for both floor and backing of walls. The thickness of this need not be more than an inch, but care should be taken that it is not less in any part than $\frac{1}{2}$ an inch. In this case the radiated well bricks should also be laid with hydraulic mortar or with cement.

588.—*Describe another method of lining the tanks.*

Another method is to use no bricks at all, but to render the sides of the excavation impervious with Portland cement in three coats, the full thickness of the cement being not less than an inch.

In this case it is very necessary that the sides be rimmed down to an exact circle. It has been objected to this method that the ground-water may rise outside the tank above the level of the water within it, and, by its hydrostatic pressure, burst off the cement lining. This would probably be so if care were not taken to make the excavation circular; but that being done, and there being necessarily an equal external pressure all round the well, the cement ring would be put under a compression not greater, in all probability, than it could withstand. If it be desired to have a brick lining, and to coat the face of that with cement, the bricks should be laid dry, to prevent settlement of mortar joints.

589.—*What would be the intrinsic cost of water under the foregoing circumstances?*

If we suppose the tank and pump to last, with a full allowance for repairs, only 30 years, there would be procured in that time 100,000 gallons of water. If we take the first cost at £6, and allow 2 per cent. per annum for repairs, or 2*s.* 6*d.* every year during the 30 years, and add 3*d.* for redemption in 30 years at 5 per cent., and capitalise that combined annual payment at 5 per cent., we shall add 55*s.* to the £6, making £8 15*s.*, or say £9. For this sum, including prospective expenses for 30 years, a quantity of 100,000 and odd gallons of water would be procured, being at the rate of about 1*s.* 9*d.* per 1,000 gallons, or 48 gallons for a penny.

590.—*How may such a well be covered?*

A well of small diameter may easily be covered with stone flags, or cast-iron plates, or it may be domed over. It is necessary to leave an air-hole in the cover, and to protect it with a hood so that it cannot be reached for mischief.

591.—*What should be the dimensions of the store-reservoir of rain-water under various circumstances in England?*

If all the rain-water is to be stored and used gradually and equally day by day, the capacity of the tank should be from about 1,000 gallons in the western counties to about 2,000 gallons in the eastern counties; but the rules of storage capacity applicable to water-works reservoirs do not apply in this case, because, in small houses, it is impossible to limit the quantity daily drawn out of the tank (although that is quite practicable in the case of a mansion), and if the proper average daily quantity be exceeded it throws out any calculation which might be made on the basis of a given daily quantity to be used. If the tank be made to hold 1,000 gallons, it will be of reasonably sufficient size for one house, and this would be contained in a space 6 feet square and 4½ feet deep, or in one 5 feet square and 6½ feet deep. But, perhaps, the cheapest tank that can be made is a well. A circular well may be sunk, 5 feet diameter, to a depth of 15 feet; and if the ground be a stiff retentive clay to that depth, a trial hole should be dug in the bottom to the depth of a foot or 18 inches to ascertain that the clay continues to a sufficient depth below the bottom of the well, the hole being carefully filled in again with puddled clay. The well may then be lined with half-brickwork in hydraulic lime mortar, leaving a clear diameter of 4 feet 3 inches. If the bricks be laid dry the water will pass through the joints to the clay at the back and dissolve it, and part of it will be washed into the well as the water-surface lowers; and if the mortar be made of other than hydraulic lime, it will be dissolved.

592.—*What impurities may be found on the roofs of houses?*

The roofs of houses are fouled by bird-droppings and by decaying vegetable matter and soot. Rain washes these off, hence in collecting rain-water from roofs the first part is to be rejected.

593.—*In calculating the area of a collecting roof what do we estimate?*

The area of the base of the house. The slopes are not counted.

594.—*Does the slope of a roof interfere materially with the result?*

It does not; but it is more accurate to take merely the flat surface area corresponding to the area of the ground-floor rooms, to which we add the sectional area of the walls and eaves.

595.—*How may we estimate the rainfall off the roof of a*

Ascertain the area* of the roof in square feet, multiply it by 144 (which brings the area to square inches) and multiply this by the rainfall, the result is cubic inches of water. To convert this into gallons, multiply by 277·274; or divide by 1,728 (cubic inches in a foot) which gives the cubic feet of water. [A cubic foot of water weighs 62·5 lbs; and measures 6¼ gallons; 1 gallon of water weighs 10 lbs.; 62·5 lbs. = 1,000 ounces = weight of a cubic foot of water.]

When roofs are used as collecting surfaces for rain-water, the first portion of rain which falls and descends from the roof should be rejected, as it is liable to be much polluted with soot, vegetable matter (leaves), and animal matters, excrement of birds, etc., washed off from the slates or tiles.

If the amount of roof space per head in a town is 60 square feet, and the rainfall 30 inches in the year, deducting one-fifth for evaporation, 207,360 cubic inches of rain (= 120 cubic feet or 748 gallons) is the amount available for each person in a year, which is equal to about 2 gallons daily. This is the amount available from the rainfall—30 inches—of an average year.

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* In calculating the area, the flat surface and not the slope is to be measured; this is represented by the total area of the rooms on the ground-floor to which is added the thickness of the walls and eaves.

One cubic foot, or 1,728 cubic inches, of water being equivalent to 6·25 gallons, the number of gallons of water can be easily calculated. It has been estimated that even if a rain-water supply for towns were desirable, the amount collected from the roofs of houses would scarcely average 2 gallons per person daily, assuming the average rainfall to be 20 inches, and that there was a roof area of 60 square feet for each individual. As the roofs of houses are—or should be—quite impermeable to water, there is no percolation or sinking in of the fallen rain.

596.—*How should it be stored?*

In underground tanks or cisterns properly constructed and secured from all forms of contamination.

597.—*What part of the rainfall can be used for storage?*

About half is lost by evaporation or percolation leaving only about 3 gallons per head.

598.—*What are the chief impurities of such water?*

Cl, NH_3, and nitrites and lime absorbed from the cement.

599.—*What precautions are to be taken in regard to the collection and storage of rain-water?*

When rain-water has to be collected from buildings and stored for drinking purposes, special precautions must be taken to ensure its cleanliness and freedom from metallic compounds and from organic impurities. For this purpose it should never be collected from surfaces of lead, and even roofs covered with sheet zinc or galvanised iron communicate some zinc to the water collected on them. Roofs covered with slate afford the best collecting surfaces for rain-water. The first water collected after dry weather is always dirty, polluted with the excrement of birds, and contains vegetable spores.

600.—*What apparatus has been invented and highly commended for the separation of gross impurities of rain-water and for its collection in a pure state?*

Mr. Charles Gay Roberts has designed a very ingenious and effective separator for automatically getting rid of the first and dirty rain-water falling after drought—the "Automatic Rain Water Separator" or "Collector," by which the first part of the rainfall is prevented from flowing into the storage tank. This is so arranged that part of the apparatus is aslant, and throws off the first part of the rain which has washed the dirt from the roof.

601.—*How is the apparatus brought into action as regards the collection of the rain-water?*

The change of position is effected by the gradual accumulation of a small portion of water in the chamber of the canter; when the water reaches a certain height, it makes the left side heavier than the right, and the canter turns a little on the pivot that supports it, so that the water is delivered two inches further to the right than it was before; and whereas it at first ran through into the waste pipe, it now runs through into the storage tank.

In a very slight rain the whole of the water passes through the strainers and a hole, and when it is not enough to effectually wash the roof it all escapes without making the canter move. When there is more rain than can pass through the hole it rises, and a small quantity runs over the side of the funnel, slowly filling the chamber. When the chamber is filled to a certain height, it over-balances the canter and makes the water run to storage. This change in position causes the water to run into one chamber and cease to run into the other. As the water sinks in one it also sinks in the other causing the apparatus of the siphon to act and empty the chamber.

As soon as the chamber is empty, the canter rights itself, ready for the next rainfall, the right hand side of the canter being heavier than the left when it is empty. By means of the joint action of the sluice and the holes the flow of water in the working part of the separator is so regulated that the chamber is filled to the canting point as soon as a certain quantity of rain has fallen.

[A vertical separator is used where a single stack pipe carries the water from the roof to the tank.]

602.—*If the people of England had to depend on roof-collected rain-water, could this provide sufficient for all purposes?*

In most English towns the amount of roof space for each person cannot be estimated higher than 60 square feet, and in some poor districts is much less. Taking the rainfall in all England at 30 inches, and assuming that all is saved, and that there is no loss from evaporation, the receiving surface for each person would give 935 gallons, or 2½ gallons a day. But as few town houses have any reservoirs, this quantity runs in great part to waste in urban districts. In the country it is an important source of supply, being stored in cisterns or water butts. If, instead of the roof of a house the receiving surface be a piece of land, the amount may be calculated in the same way. It must be understood, however, that this is the total amount reaching the ground; all of this will not be available; some will sink into the ground, and some will evaporate; the quantity lost in this way will vary with the soil and the season from the one-half to seven-eighths. To facilitate these calculations, tables have been constructed by engineers.

603.—*Give a Table showing the daily yield of water from a roof of given area with varying rainfalls.*

Area of House, 10 feet by 20 feet, or 200 square feet.

Mean rainfall.	Loss from evaporation.	Requisite capacity of Tank	Mean daily yield of Water.	Mean daily yield of Water in wettest year.	Mean daily yield of Water in driest year.
Inches.	Per cent.	Cubic feet.	Gallons.	Gallons.	Gallons.
20	25	100	4·3	6·7	3·2
25	20	135	5·7	7·5	3·9
30	20	145	6·8	9·4	4·5
35	20	155	7·9	11·0	5·0
40	15	165	9·7	13·1	7·2
45	15	170	10·9	14·2	8.6

For any other size of roof or amount of rainfall, the numbers will be proportional.

The amount of evaporation from the surfaces of roofs may be taken as averaging throughout the year 20 per cent. of the rainfall. The evaporation is greatest where the rainfall is least, and *vice*

604.—*How may we find the amount of rain-water that can be collected from any roof?*

Reduce the area to square inches, multiply by the rainfall, and the result by ·003607 to find the number of gallons supplied, or by ·00058 for cubic feet. One inch of rain gives 4·673 gallons for every square yard, or 22,617 for each square acre.

605.—*Give an example as to the method of calculating the rainfall from a prepared receiving surface and from a roof.*

Suppose the rainfall to be 20 inches per annum, and the area of the receiving surface 500 square feet. Multiply the area by 144, to bring it into square inches, and this by the rainfall, and the product gives the number of cubic inches of rain which fall on the receiving area in a year.

606.—*What is the supply in the case of a house* 40' × 20' *with* 42 *inches of rain per annum?*

A house 40 feet by 20 feet, *i.e.*, covering 800 square feet, would receive upon its roof, with a rainfall of 42 inches, 2,800 cubic feet of water in the course of the year. This would be about 21,000 gallons, or about 60 gallons per day on the average.

Care should be taken that the numbers multiplied together are brought to the same denomination. In estimating the amount of rain that can be collected from a sloping roof, take the area as that of a transverse section of the house including walls and eaves; that is, take the area of the ground covered by the roof. If the average rainfall be 20 inches, it would only give 2 gallons per day to each person if collected only from roofs of houses in towns, assuming each house to have an average roof area of 60 square feet to each individual.*

607.—*Express in gallons, an inch of rain per square yard.*

4·673 gallons.

608.—*How many square yards in an acre?*

4,840.

609.—*What are the various equivalents of one inch of rain over an acre of ground?*

An acre consists of 6,272,640 square inches, so that one inch of rain falling on any day gives 3,630 cubic feet of water to the acre, 22,622 gallons, or 2,262,250 lbs.; which divided by 2,240 (lbs in a ton) gives 101 tons (approximately) of water per acre. For every $\frac{1}{100}$th of an inch one ton of water must be calculated.

610.—*How is the amount of water provided by rain calculated in a given place?*

By multiplying the rainfall into the area of the receiving surface.

611.—*Is rain-water collected from roofs of houses always of reliable quality?*

It is not; the rain-water collected from the roofs of houses and stored in underground tanks is often impure; it is often polluted to a dangerous extent by excrementitious matters, and is rarely of sufficiently good quality to be employed for dietetic purposes with safety.

612.—*Whence is rain-water usually collected?*

It is usually collected from the roofs of houses, and occasionally from paved or cemented and prepared ground.†

613.—*How are the channels of the gathering ground formed?*

They may either be the natural watercourses of the district or these may be supplemented by closed drains or open ditches.

614.—*What is the objection to open ditches as channels?*

They form receptacles for vegetation, and as the current in them must necessarily be slow, there is considerable loss by evaporation. The position, extent, and dimensions of the drains leading to the reservoirs will depend upon the configuration of the district.

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* ALLEN's *Aids to Sanitary Science.*

† See HEHIR's *Hygiene of Water and Water-supplies.*

615.—*How may rain-water be filtered?*

For the filtration of rain-water it is a common practice to construct a filter underground, in which case certain precautions are necessary. It is essential that the brick which contains the sand and the gravel should be built in cement, so as to render it impervious to soakage from the surrounding soil. Sometimes, in addition to sand and gravel, charcoal is introduced, but this is objectionable, because the water has afterwards to be stored, and charcoal imparts to water a material which favours the growth of vegetable micro-organisms. Such filters as these are apt to be neglected, on account of their inaccessibility. It is not easy, even if every facility is offered, to induce the public to systematically cleanse and inspect them, but if any difficulty stands in the way of doing so, it is hopeless.

616.—*What quantity of water is there in an inch of rain per acre?*

About 101 tons, 3,630 cubic feet, or 22,622 gallons.

617.—*What are the various equivalents of different volumes of water? Give also the various factors required in rain-water, and public water-supply calculations.*

1 gallon=10lbs =·1605 cubic feet=70,000 grains,
=4·5434 litres=277·273 cubic inches.
224 gallons=1 ton=35·942 c. feet=1·331 c. yards.
1 pint=34·6592 cubic. inches=1·25 lbs.=0·206 c. feet=·5679 litre=8750 grains
1 fluid ounce=1·72 cubic inches=437·4976 grains.
1 dram avoir.=27·3436 grains.
1 cubic inch =252·5 grains.
35·942 c. ft. =1 ton.
1 cubic yard =168·2694 gallons.
1 cubic foot =997 ounces (or approximately 1000 ounces)
1 foot of water at 62° F.=62·4 lbs. pressure on the square foot.
Do. = 0·4333 lbs. on square inch.
Do. = 0·0295 atmosphere.
Do. = 0·8823 in 32° F.
Do. =773 feet of air at 32° F. and 1 atmosphere.
1 lb. on square foot =·016 feet of water.
1 atmosphere of 29·992 inches of Hg.=33·9 feet of water.
1 inch of Hg. at 32° =1·9334.
1 foot of air at 32° F. and one atmosphere=·001294.
1 foot of average sea-water=1·026 ft. of pure water.

The amount of water given by rain is calculated from (1) amount of rainfall, and (2) the area of the receiving surface.

The former is ascertained by a rain-gauge; the area must be measured (4,840 square yards=one square acre; 640 square acres= one square mile, and 9 square ft.=1 square yard); then area in sq. feet × 144 (to bring to square inches), × rainfall= total amount (in cubic inches) on area in given time.

Product (in cubic inches) ÷ 277·274, or × 0·003607 = number of gallons.

One inch of rain=4·673 gallons on every square yard, equal to 101 tons of weight on each square acre.

One cubic foot of water=6·2355 gallons (6¼ approximately).
Inches of rainfall × 3630=cubic feet per acre.
,, × 2,323,200=cubic feet per square mile.
,, × 14·5=million of gallons per square mile.
Number of feet of rain × 193,600=cubic feet per square mile.
,, × 302·5 =cubic feet per acre.
Feet per second × ·68=feet per mile.
,, × 20=yards per hour.
Cubic feet per second × 6¼=gallons per second.
,, × 375=gallons per minute.
,, × 22=thousands of gallons per hour.
,, × 500=thousands of gallons per diem.
,, × 2400=tons per diem.

618.—*What is meant by Monsoons?*

Just as breezes are set in motion by the accumulated heat of the day and the radiation during the night, so the accumulated summer heat and winter cold over large continental areas is sufficiently powerful to set in motion, seasonal or periodic winds, known as "*Monsoons*" (from an Arabic word meaning "season"), blowing half the year in one direction and the other half in the opposite direction and even reversing the Trade Winds. Though local monsoons are produced on the Guinea coast by the Sahara, and in the Western North America by the great plateau in that region, the chief to which the name was originally applied are those of India, or rather, of Central Asia which are so intensely heated as to have an average temperature of 90° F. and consequently became the centre of a low pressure area. Air flows into this area from all sides—from Siberia on the north, from China on the south-east, from India on the south and from Europe on the west. In winter, on the other hand, matters are reversed, the temperature falls to the freezing point, the pressure rises proportionately, and the wind flows out in all directions. This winter wind the North-East Monsoon of India blowing from October to April over the Himalyas, is a cool dry wind, whilst from April to October the hot South-West Monsoon blows from the Indian Ocean laden with moisture, which is precipitated in contact with the mountains.

619.—*Explain the formation of Dew.*

When a glass or metal goblet of cold water is brought into a warm room its outer surface is dimmed with minute drops of water condensed from the moisture in the surrounding air, in like manner on a clear summer evening the blades of grass become covered with *dew*. If the sky is cloudy the air will be warmer and dew will not form. Grass and other leaves freely radiate, or give off into space, the heat they have received during the day, and the air around them is gradually cooled down to its point of saturation or dew point, when the dew will be deposited. Clouds, however, obstruct this radiation, and so make the night warmer and hinder the formation of dew, which is therefore more copious on a clear night. The soil does not radiate heat so as to fall below the temperature of the adjacent air as readily as do the leaves, and therefore the dew is mainly precipitated upon them. In hot countries, where the amount of aqueous vapour in the air is very great, the copious dews are of much service in long droughts or in rainless areas.

620.—*What is meant by the Snow-line?*

The snow line or line of perpetual snow, is a line above which the snow never entirely melts. Within the tropics this line is about 16,000 feet (three miles) above sea-level. At Quito, near the Equator, it is at 15,800 feet; in Mexico, 19° N. at 14,800; on the south side of the Himalayas, which is supplied with abundant moisture from the Indian Ocean, it is at 16,200 feet, but on the north side, which is heated by the dry air from Thibet, at 17,400. In Granada, lat. 37° N., it is at 11,200 feet, and on the Mount Blanc, lat. 46° N., 8,500 feet. No point in the British Isles actually reaches the snow line. In Iceland, in lat. 60° N., it is at 3,100 feet; in the Island of Mageroe, on the North Coast of Norway 2,000 feet, and at Spitzbergen at the sea-level.

621.—*Explain the formation of Mist.*

On a still summer evening the valleys of streams and the surface of lakes often become covered with a *mist* or cloud. This is produced by the radiation from the ground being more rapid than that from the water, so that the vapour given off from the latter is chilled and condensed. Mists also form commonly on mountains, when a warm wind strikes upon their slopes and ascends into colder altitudes. A mist only differs from a cloud in being close to the ground. Clouds are always raining, since the drops of which they are composed always tend to obey the action of gravity.

622.—*Explain the condensation of atmospheric vapour.*

Just as steam is visible inside a flask half filled with boiling water, or as it is leaving the spout of a kettle or the funnel of an engine, and as it comes into contact with the cold outer air is condensed into a cloud of minute drops of water, so the moisture in the air is condensed into what is sometimes called *visible vapour* when the temperature is lowered or when the moisture-laden air ascends to colder regions of the atmosphere. This leads to the formation of dew, hoar-frost, mist, cloud, rain, snow, or hail, the various forms in which the *precipitation* of atmospheric moisture takes place.

623.—*Explain the formation of Hoar-frost.*

When the temperature near the ground falls very low from excessive radiation, as in a still clear night in winter, the dew as it forms, instead of appearing as small drops of liquid crystallises into solid, geometrically regular particles, or crystals of ice. It is then known as *rime* or hoar-frost. Windy weather is unfavourable to the formation of dew or hoar-frost, as the air is carried away as rapidly as it is cooled.

624.—*What is Hail?*

Hail is probably due to the freezing of rain-drops in their passage through strata of air colder than those in which they were formed—drops of rain more or less suddenly formed.

625.—*Explain the occurrence of Hail. When does Hail generally fall?*

It is generally in hot weather, especially in summer and in connection with thunder-storms that precipitation takes place in the form of hail. Hail consists of pellets of ice, generally conical-shaped and denser at the base, the apex being often broken on striking the ground. The hailstones are believed to originate in a very sudden condensation of the moisture in one atmospheric current in contact with another. They vary in size and become apparently striated by agglutination in falling. In tropical and sub-tropical storms the hailstones are sometimes as a large as a hen's eggs, or even larger.*

626.—*What peculiar phenomena arise from the formation of small crystals of ice in the air?*

In cold countries the air is often filled with small crystals of ice which give rise to the phenomena of haloes and parhelia.

627.—*What is Sleet?*

Half-melted snow, and it is in the intermediate condition between this and rain.

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* In a recent hail-storm in Hyderabad the hailstones weighed an ounce each. (See *Indian Medical Record*, March 1893, for a description of that hailstorm.)

628.—*What is the equivalent of one inch of rainfall in 24 hours in cubic feet over an acre of ground?*

Rainfall at the rate of one inch in 24 hours delivers upon each acre of drainage area about 2·5 cubic feet of water each minute.

629.—*By what formula may we ascertain the amount of rain?*

Area in square feet × by 144 × rainfall in inches ÷ 1728 = cubic feet.
Cubic feet × 6·24 = gallons
or simpler, in which the error is 4 per cent :—
Area in square feet × half the rainfall in inches = gallons.
1 inch of rain delivers 4·673 gallons on each square yard.
„ „ 22·617 „ „ „ acre.
„ „ 101 tons „ „ „

[The average rainfall for all England is 30 inches annually.]

630.—*What is the equivalent of an inch of rain over a square yard and a square acre?*

One inch of rain delivers 4·673 gallons on every square yard, or 22,617 gallons (101 tons by weight) on each square acre.

CHAPTER VI.

QUANTITY OF WATER REQUIRED.

631.—*What quantity of water is daily consumed by an adult man?*

From 70 to 80 ounces.

632.—*How much is (a) actually drunk, and (b) how much is taken into the system in the so-called solid food?*

(*a*) From 50 to 60 ounces is drunk, and (*b*) from 20 to 30 ounces is contained in solid food.

633.—*How much water does a healthy adult male require per diem?*

A healthy adult requires daily from 70 to 100 oz. of water for the process of nutrition, about one-third of which is contained in articles of diet (in the so-called dry food), the other two-thirds being supplied in the form of liquid.

634.—*How much water is ingested daily per pound weight of body?*

Half an ounce per pound weight of body.

635.—*By what organs of the body is water lost?*

We are constantly throwing off a lot of water from our body—from the *lungs* in the form of watery vapour; from the *skin* in the form of sweat; and from the *kidneys*, as urine; a small quantity is also lost in the fæces.

636.—*Give a table showing what you consider to be the least, greatest, and the average supply of water per head in a manufacturing town, specifying the purposes for which the quantities stated are required?*

	Gallons per day per head.		
	Least.	Greatest.	Average.
Used for domestic purposes ...	7	15	10
Washing streets, extinguishing fires, supplying fountains ...	3	3	3
Allowance for trade and waste ...	7	7	7
Total in non-manufacturing towns ...	17	25	20
Additional demand in manufacturing towns ...	10	10	10
Total in manufacturing towns ...	27	35	30*

637.—*In gross amounts what is Professor* RANKINE'S *estimate?*

An estimate of 10 gallons daily per individual for domestic purposes, 10 for municipal purposes, and 10 more for trade purposes in manufacturing towns.

638.—*What quantity of water is required per head of population?*

After giving considerable attention to this subject, the late Professor E. A. PARKES arrived at the conclusion that 25 gallons per head, per diem, is the minimum quantity of water to be allowed. In places where sewers are in existence, it is necessary that this amount of water should pass through the house drains into them, in order to guarantee the complete removal of all solid waste and keep the sewers clean. [In England many poor families, either from the difficulty of obtaining water or of getting rid of it, or from the habits of uncleanliness thus handed down from father to son, use an extremely small amount. It would be quite incorrect to take this amount as the standard for the community at large, or even to fix the smallest quantity which will just suffice for moderate cleanliness. We have proved, from special observations made on the subject, that the ordinary village occupant (in Hyderabad, Deccan, India) does not use more than two gallons of water a day (unless the well is at his very door), a quantity altogether inadequate to effect the least semblance to domestic or personal cleanliness.]

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* From Prof. RANKINE'S *Civil Engineering*.

639.—*How much should be allowed for town and trade purposes?*

For washing streets, alleys, courts; for extinguishing fires, for fountains, public water-closets and urinals, allowance for trade in some manufacturing town 5 gallons; and for exceptional manufactories 5 gallons.

640.—*How much water per head is required in a rural village without sewers?*

About 12 gallons per head, per diem.

641.—*How much in a manufacturing town?*

About 35 gallons per head, per diem.

642.—*How much in a non-manufacturing town?*

About 25 gallons per head, per diem.

643.—*If 25 gallons per head per diem be supplied in general terms how would it be distributed?*

(*a*) For domestic purposes,	12 gallons.
(*b*) General bath,	4 ,,
(*c*) Water closets,	6 ,,
(*d*) Unavoidable waste,	3 ,,

644.—*Is this quantity of water actually necessary?*

It is in "sewered" towns, for it requires this quantity to keep the sewers free from deposit. [In towns such as Oxford, Norwich, etc., where the old-fashioned privies still exist, from 10—12 gallons may be enough.]

645.—*In apportioning the daily allowance for all purposes, what scale did the late Professor* PARKES *lay down?*

Domestic supply ...	... .	12 gallons.
General bath	... ...	4 ,,
Water closets	... ...	6 ,,
Unavoidable waste	... ...	3 ,,
		25 gallons.
Municipal purposes	Street watering Extinguishing fires	5 gallons.
Trade ...	... ...	5 ,,
		35 gallons.

The following table gives in a collected form the quantities required on an average for various purposes:—

Domestic use:	Gallons per head daily:
Drinking (besides which 20 to 30 ounces is taken in bread, meat, etc.)	0·33
Cooking	0·75
Ablution, including sponge-bath, 2½ galls.	5·00
Share of utensil and house-washing ...	3·00
Share of clothes-washing	3·00
Water-closets...	6·00
General bath (weekly about 30 gallons) ...	4·00
Unavoidable waste	3·00
	25·08

646.—*Is this quantity absolutely needed in towns?*

It is. [All towns with water-closets require 25 gallons per head per diem to keep the sewers clean and free from deposit.]

647.—*For what additional purposes is water required?*

Town and trade purposes:	
Washing streets, courts, etc., extinguishing fires, supplying fountains, etc., allowance for trade and for animals in non-manufacturing towns (varies; London has 18 gallons)	5·00
Allowance for exceptional manufactures.	5·00
	10·00
Making a total of	35·08

648.—*Upon what data was the above-mentioned quantities stipulated?*

In fixing the above quantities, viz., 12 gallons per head for all domestic purposes except general baths and closets, 4 gallons additional for general baths, and 6 for water-closets, endeavours have been made to base them upon facts, and they are probably not much in error. It is, however, necessary to make some allowance for unavoidable waste within the premises and for extra supply to closets, and it will be a moderate estimate to allow 3 gallons daily per head for this purpose. This will make 25 gallons.

amount of water is allowed per head in the British Army?

Fifteen gallons. [No allowance is made for the wives and children of British soldiers.]

650.—*How much water per head is usually supplied in towns?*

25 gallons.

651.—*How much of this is used, and how much goes to waste?*

The ordinary calculations for unavoidable waste is 3 gallons. But there are reasons for considering that in many cases as much as ⅓rd goes to waste through leakage at joints of pipes.

652.—*What is Sir James Rawlinson's minimum estimate for manufacturing towns?*

It is 20 gallons per head daily.

653.—*How much may ordinarily be allowed for cooking purposes?*

The amount of cooking has been estimated at from half a gallon to a gallon daily for each person.

654.—*In supplying a town, what amount of water should be aimed at?*

Fifty gallons per head per day.

655—*What amount does the hydraulic engineer fix as his standard in estimating the demands of a town?*

Fifty gallons per head per diem

656.—*What is the least quantity of water allowable per diem for each individual?*

If restriction in quantity is compulsory, four gallons per diem is the least quantity allowable.

657.—*What is considered to be the minimum allowance for personal and domestic use?*

12 gallons.

658.—*Allowing for baths, water closets and waste, what is considered the minimum supply allowable in towns?*

About 25 gallons.

659.—*What is the least allowance where personal and domestic cleanliness is to be maintained?*

12 gallons per head per diem.

[It is generally estimated that from ten to fifteen gallons of water per head per day are required for personal and domestic use, five to ten gallons for municipal purposes, and a similar quantity for trade purposes, but all these items are liable to very wide variation. About twenty or thirty gallons per head are supplied in most towns in Great Britain. The average daily amount taken in food is about half a gallon, but at least a pint of this is contained in solid food. Half a gallon more is used in cooking. Parkes allows in a middle-class household six gallons per head for domestic washing, five for ablutions including a sponge bath, six for water-closets, four for general baths, and three for unavoidable waste.*]

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* WHITLEGGE'S *Hygiene and Public Health.*

660.—*How much water is required for an ordinary bath ?*

From 18 to 20 gallons.

[*N.B.*—A man weighing 12 stones occupies 3 cubic feet of space which is represented (approximately) by 19 gallons of water.]

661.—*How much water is required for an ordinary full length or a plunge bath ?*

From 40 to 60 gallons of water.

662.—*Calculate this cubic capacity from the fact that a man 12 stone in weight can just float in water.*

A man in floating displaces his volume of water, and it has been calculated that a man of this weight displaces 19 gallons of water which has a cubic capacity of 3 cubic feet (approximately).

663.—*What additional allowance is to be made where water-closets are used ?*

An additional allowance from 4 to 6 gallons must be provided. Latrines require a less amount.

664.—*Discuss the question as to the amount for water-closets.*

The common arrangements with cisterns allow any quantity of water to be poured down, and many engineers consider that the chief waste of water is owing to water-closets. In some districts, by attention to this point, the consumption has been greatly reduced; in one case from 30 to 18, and in another from 20 to 12 gallons per head. It has not yet been precisely determined what quantity should be allowed for water-closets. Small cisterns, termed water-waste preventers, are usually put up in towns with constant water-supply, which give only a certain limited amount each time the closet is used. The usual size now in use holds about 2 gallons; but even 2 gallons are often insufficient to keep the pan and soil-pipe perfectly clean. This depends a good deal upon the kind of closet used.* The water-waste preventers must be sometimes allowed to fill again, and be again emptied. Considering also that some persons will use the closet twice daily and sometimes oftener, and that occasionally more water must be used for thoroughly flushing the pan and soil-pipe, 6 gallons a day per head should probably be allowed for closets. In this particular instance a false economy in the use of water is most undesirable. Water latrines require less; the amount is not precisely known; the experiments of the Royal Engineers at Dublin give an average of 5 gallons per head, but it is considered this might be reduced.

665.—*If baths, water-closets, personal and domestic cleanliness are maintained, what quantity should be allowed ?*

Twenty-five gallons per head per day.

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* PARKES' *Practical Hygiene*, 7th Ed.

666.—*How much water does the Act of Parliament allow for each flush of the closet?*

Two gallons for each flush; but this is too little to flush the basin and clear the traps well: and the further off the water-closet is from the main sewer the more water it requires.

667.—*What is the minimum amount of water required in water-closet cisterns, and under what conditions should its mechanism operate?*

The water-supply should not be less than 2 gallons for each time of use; the amount and force should be sufficient to wash everything through the syphon. Water-waste preventing cisterns only should be connected directly with the supply of water-closets; the best are those that work by syphon action, one pull of the wire being sufficient to set it going; the cistern should be at least 4 feet above the pan.

668.—*How much per head per diem should pass into each pan?*

Six gallons.

669.—*What should be the least amount in each flush?*

Two gallons.

670.—*What is the regulation quantity of water in each flush of the closet?*

Two gallons.

671.—*Mention a simple means of reducing waste from carelessness?*

That of compelling those who use the water to pay in accordance with the quantity used as measured by the water metre.

672.—*What is the great hygienic disadvantage in this method?*

That of leading to scanty use of water, with all its evils, especially amongst the poorer classes.

673.—*How much should be allowed per patient in hospitals?*

Forty-five gallons per patient.

674.—*How would this quantity be distributed in hospitals?*

Drinking, cooking, kitchen utensils	3	gallons.
Personal washing and general baths	20	„
Laundry washing	5	„
Hospital washing, cleaning utensils, etc.	5	„
Water closets	12	„
Total...	**45**	**gallons.**

675.—*How much water is required to keep sewers clean?*

Twenty-five gallons per head per diem are required to keep ordinary well-laid sewers clean; but extra water has to be used from time to time for flushing purposes.

676.—*Does the question of quantity of available supply concern the sanitary officer in a projected public water-supply?*

Not as a rule, it being out of his province, but although it is true that this question is one which concerns mainly the engineer, one of the first sanitary requirements is an abundance of water and, as in many instances the quantity actually obtained has fallen far short of that anticipated, it is not out of place to emphasize the importance of the preliminary examination.

677.—*Name some trades needing a large amount of water?*

Paper-making and gelatine-making. The manufacture of gelatine uses up as much water as 10,000 persons would.

678.—*Would the amount collected from roofs in England suffice for all purposes were it depended upon?*

It would not; for it has been estimated that the quantity which can be collected from the roof surface of any town in England will scarcely amount to 3 gallons per inhabitant daily, assuming that the average rainfall is 30 inches, and that house-accommodation gives a roof area of 60 square feet for each individual.

679.—*What amounts are supplied in different parts of London?*

	Gallons per head of population daily.
New River Company in London, 1879	28·7
East London Water-Works Company ,, .	34·2
Kent ,, ,, ...	29·1
Chelsea ,, ,, ,, ..	36·5
West Middlesex ,, ,, ,, .	26·5
Grand Junction ,, ,, ,, ...	32·9
Southwark and Vauxhall ,, ,, ...	40·9
Lambeth ,, ,, ...	31·5
Average of these eight London Districts ...	32·7

680.—*Name some towns that do not need these comparatively large quantities?*

Oxford and Norwich. [These towns use the old form of privies and not water-closets.]

At Norwich about 14½ gallons daily per head are supplied on the constant system, of which 10·5 are taken for domestic purposes, 3 for trade, and ·7 gallons for public and sanitary purposes. In Manchester the supply is also constant, and is 14 gallons per head for domestic, and 7 for trade purposes. In 1878 in 15 American cities the supply was on the average 55 gallons per head.

681.—*What is the average amount per head supplied to towns?*

In 1857 the average supply to fourteen English towns, of second-rate magnitude, was 24 gallons. The average of 72 English and Scotch towns, supplied on the constant system, is 134·4 gallons per house (but this includes the supply to factories, of which there were 16,087 to 889,028 houses), or (at 5 persons to each house), 26·7 per head; of 23 towns, supplied on the intermittent system, 127 per house, 25·4 per head, including 1,367 factories to 137,414 houses; and of London, also on the intermittent system, 204, or 41 per head, including 5,340 factories to 499,582 houses. The range in individual cases is, however, very great, from 25 gallons per house (5 per head) in one small town to 700, at Middlesborough (140 per head). Mr. Bateman has stated that in the manufacturing towns of Lancashire and Yorkshire the amount was from 16 to 21 gallons, in some cases less.*

682.—*What is Professor RANKINE'S estimate for towns?*

The following table is given by Professor RANKINE:—

	GALLONS PER DAY PER HEAD.		
	LEAST.	GREATEST.	AVERAGE.
Used for domestic purposes	7	15	10
Washing streets, extinguishing fires, supplying fountains	3	3	3
Allowance for trade and waste ..	7	7	7
Total in non-manufacturing towns ...	17	25	20
Additional demand in manufacturing towns	10	10	10
Total in manufacturing towns ...	27	35	30

On the whole, it may be said that not less than 30 gallons per head daily should be supplied to every town.

683.—*Give a table of the number of gallons of water supplied daily per head in different places.*

London—New River Company	23
„ East London	22
„ Chelsea	33·8
„ West Middlesex	30
„ Grand Junction	34
„ Southwark and Vauxhall ...	21
„ Lambeth	34
Southampton	35
Glasgow	50
Edinburgh	35

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* PARKES' *Practical Hygiene*, 7th Ed.

Liverpool	30
Sheffield	20
Nottingham	17
Derby	14
Norwich	12
Soldiers in Barracks	15
Paris	31

684.—*Give instances of large supply.*

New York	83 gallons.
Rome	100 „
Glasgow...	51 „

685.—*Is the same quantity of water used in towns throughout the year?*

It is not; the daily quantity used varies to the extent of about 20 $^{0}/_{0}$ on the average in towns.

686.—*Does all this reach the consumer?*

It does not; as a rule from ½ to ⅓ goes to waste.

687.—*In what parts of the water system does the waste occur?*

In the pipes, at the hydrants, and in the house.

688.—*In which of these is the greatest waste?*

In the pipes

689.—*Is there any relation between the system of the distributing area and the loss?*

There is; the smaller the area the greater the waste.

690.—*How is the amount of supply usually stated?*

In towns supplied by water companies, the usual mode of reckoning is to divide the total daily supply in gallons by the total population, and to express the amount per head per diem.

691.—*Is the amount of domestic consumption of water uniform?*

It is not; calculations have shown that there is a very perceptible daily variation in each week, and hourly variation in the consumption in each day.

692.—*What quantity of water is supplied to the population of London and from what sources is it derived?*

In 1884 the total population of the metropolis and suburbs was reckoned at 4,944,553, and the water supplied daily by all the eight companies was 139,805,082 gallons, or 29,433,516 cubic feet. This gives 28·3 gallons or 4½ cubic feet per head. Of the total amount, 110,000,000 gallons are from the Thames (restricted to that amount); the rest, that is, the New River, East London, and Kent, are from the River Lea and from wells, the quantity being unrestricted.*

693.—*How much water would you allow for different animals?*

For horses and cows, about 6 to 10 gallons.

For sheep and pigs, about ½ to 1 gallon.

694.—*What amount is allowed for an artillery and for a cavalry horse?*

Ten and eight gallons, respectively. [From experiments conducted in some cavalry stables in 1866, by the Royal Engineers, the War Office authorities have fixed the daily supply for cavalry horses at 8 gallons, and for artillery horses at 10 gallons per horse. This is to include washing horses and carriages. The amount seems rather small. Of course the amount that horses drink varies as much as in the case of men, and depends on food, weather, and exertion; but if a horse is allowed free access to water at all times, and this should be the case, he will drink on an average 6 to 10 gallons, and at times more. In the month of October, with cool weather, a horse 16 hands high, doing 8 miles a day carriage work, and fed on corn and hay, was found to drink 7½ gallons. Another carriage horse drank nearly the same amount. In a stable of cavalry horses doing very little work, and at a cool time of the year, the amount per horse was found to be 6⅓ gallons. Taking a horse as weighing 1,000 lb. avoir., this is just an ounce of water per lb. weight of horse. The amount used for washing was 3 gallons daily.

695.—*What should be the amount of water-supply in the Tropics?*

It should practically be unlimited.

696.—*What quantities of water should be procured for different purposes in hot countries such as India?*

In India and hot countries generally, the amounts now laid down would have to be altered. Much more must be allowed for bathing and for washing generally, while a fresh demand would arise for water to cool mats, punkahs, or air-passages by evaporation. In Calcutta it was intended to supply to Europeans 30 gallons per head and to natives 15 gallons daily, but the amount has been really much less up to the present time.

697.—*What amount is required for sick men?*

In hospitals a much larger quantity must be provided, as there is so much more washing and bathing. From 40 to 50 gallons per head are often used. There are no good experiments as to the items of the consumption, but the following is probably near the truth :—

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* PARKES' *Practical Hygiene*, 7th Ed.

	Gallons daily.
For drinking and cooking, washing, kitchen and utensils.	2 to 4
For personal washing and general baths ...	18 to 20
For laundry washing	5 to 6
Washing hospital. utensils, &c.	3 to 6
Water-closets	10 to 15
	38 to 51

698.—*Give the amount supplied per head to some of the larger hospitals of Great Britain?*

At Netley the amount per head per diem is put approximately at 56 gallons (Major Nixon, R.E.), at Haslar the quantity is the same. At the Cambridge Hospital, Aldershot, the average is 160; Herbert Hospital, Woolwich, 89. In some of the Metropolitan hospitals there is singular diversity in the quantities. The London Hospital expends 62 gallons per head per diem, but they have a laundry on the premises; St. Thomas's (no laundry), no less than 99; St. Bartholomew's (no laundry), 40 gallons; whereas at Guy's, where there is a laundry, but where special care is taken to check unnecessary waste, only 20 are used. In Glasgow the amounts are: Royal Infirmary, 147 gallons; Western Infirmary, 119; Sick Children's, 55; Belvidere (infectious diseases), 97, daily. At the Edinburgh Royal Infirmary water is supplied free by Act of Parliament, and no note is taken of delivery or consumption. London hospitals use from 20 to 99 gallons, while Glasgow averages 147 gallons. (Probably there is considerable unchecked waste at many hospitals.)

699.—*How much should be allowed for each patient per diem?*

For hospitals the daily amount per patient may be estimated at about 40 or 60 gallons, or twice that required for healthy persons. In prisons and workhouses the quantity will vary according to the bathing arrangements, and whether water-closets are used.

700.—*What is the cubic capacity of 1,000 oz. of water?*

One cubic foot.

.—*With regard to the water-supply how many people at the rate of 10 gallons per head per diem will a square mile of surface collecting one foot in depth, supply?*

47,580 people.

CHAPTER VII.

PUBLIC WATER-WORKS.

INTRODUCTION, REQUIREMENTS OF A PUBLIC WATER-SUPPLY, ETC.

702.—*In contemplating the opening of a new system of public water-supply, what are the main points to attend to?*

1. Whether or not the supply is *permanently* equal to the demand;
2. That the water at its source is pure, and that its purity can be maintained until it reaches the taps and hydrants;
3. The accessibility of the water at its source, but particularly when distributed; and
4. The cost of the scheme, and the expenses associated with its maintenance.

703.—*In connection with a public supply of water for towns, what is the first point that demands attention?*

That of estimating the quantity of water required for the town in gallons per diem which is obtained by fixing the amount to be allowed for each individual as given in the population census, including the quantity required for fires, fountains, washing streets, etc., as extras.

704.—*What is the more important factor in estimating the question of quantity required for a town?*

The rainfall of the three driest consecutive years.

705.—*In the absence of definite information what points are to be considered?*

The configuration of the country in regard to water-supply. [Springs at the foot of hills are permanent; in flat districts the supply is doubtful, unless derived from a great depth; in limestone regions springs from subterranean reservoirs are permanent; in chalk districts springs are few unless below the level of the country generally; similarly where sandstone obtains, but when there are deep wells, large reservoirs must have been tapped. Water from granitic and trap-rock formations is variable unless from lochs.]

706.—*What is one of the main objects served by water-works?*

With reference to the maintenance of the purity of water until it is finally distributed, one of the main objects of public water-works is to exclude water from the possibility of contamination by the various processes in constant operation, in open or exposed water-supplies. In the pipes (when of good construction and properly jointed) the water is secured from pollution.

707.—*What are the requirements of a good water-supply?*

These may be enumerated as follows:—

1. That every person in the community should get at least 12 gallons of water a day. The nearer the quantity is to 30 gallons, the better. These 12 gallons should reach the taps and hydrants. The source of supply should be as distant as possible from human habitations, one situated among distant hills being very desirable. Any source of supply would probably be better than those in general use at present, *viz.*, shallow wells, streams and rivers.

2. The water should be as free as possible from all organic and inorganic impurities; it should be hygienically pure at its source, and this purity should be maintained till the water reaches the ultimate distributing taps and hydrants. It is with the object of removing from the masses of the people the power of contaminating the drinking-water, that we should endeavour to get a supply from a locality where no such polluting influences are in existence. The wells of most towns and villages, originally containing pure water, have, in process of time, been rendered so unwholesome as to be almost dangerous to use, and this is chiefly owing to the foul habits of the people.

It is presumable that the water provided by public water-works is fit for use as a beverage direct from taps and hydrants, and as a general rule the presumption is warranted by the result of analysis of such waters; sometimes however they require further purification by domestic filtration. On the other hand we have seen the filtrate from domestic filters more impure than the water from the hydrant itself. Hence the value of periodical analysis of hydrant and tap-water. The result of these analyses should be published.

3. That the 12 gallons be available at any period of the 24 hours, *i.e.*, the supply should be *constant*. This is a matter of great importance on account of the liability of stored water to contamination. To keep the stored water of a house cistern pure requires more care and attention than the ordinary inhabitant is disposed to give. In India this cistern would probably be chiefly represented by large (and often foul) earthenware gurrahs, or brass utensils. We know that water readily absorbs impurities coming into contact with it; but other and more dangerous sources of pollution are only too abundantly present as a rule.

4. There should be no partial dependence for this supply upon wells. Wells, belonging to individual houses, whether in use or not, should all be closed, except in cases where the house is too remote from the public water-works supply.

5. A less urgent necessity than those enumerated is, the construction of drinking-water fountains, in various parts of a town or municipality, to yield a drink of pure water to the weary labourer, and worn-out beast of burden.

6. The administrative control over this water-supply should be in the hands of the local municipal authorities. It may be considered the duty of every local municipal body to endeavour to provide an adequate supply of pure water for the community. The clauses with reference to this in the various Municipal Acts are unequivocal. The process of supplying water on a large scale, can be most satisfactorily, efficiently and speedily carried out by municipal corporations under the auspices of local governments. Municipal commissioners have extensive powers, and they can levy water-rates and collect them. The large initial outlay is the usual barrier, but most municipalities of any size are now in a position to borrow money for the purpose of constructing water-works. It should be remembered that such money is merely lent, and lent for a very praiseworthy object, that of providing a community with a permanent supply of wholesome water.

The various conditions we have enumerated as necessary for a supply of wholesome water urgently require fulfilment in a large number of towns and municipalities in India. The vast majority of towns are still unprovided with a proper water-supply, notwithstanding that in many of them all these conditions are attainable; and in point of fact, the number in which they cannot be complied with is comparatively small. We may quote one instance, that of the Kurachi water-works, to show that apparently insuperable obstacles may be overcome in respect of water-supply. This instance is all the more remarkable if we remember that the average annual rainfall at that station is only about 7 inches.

708.—*Enumerate some of the advantages of a good public water-supply?*

Water has thus far proved the most effectual and economical agent, as sanitary scavenger, in the removal from our habitations of waste slops and sewage, and also the most effectual and economical agency in the protection of life and property from destruction by fire. Capital is always wary of investment where the elements of safety and health are lacking, and industry dreads frequent failures and objectionable quality in its water-supply.

Many of our Water-Supply Reports show annual incomes from water-rates in excess of the combined annual operating expenses and interest on the capital expended. In addition to this cash return, there are in all cases benefits accruing to the public, usually exceeding in real value those of the more generally recognized money income, amongst the incidental advantages. We may mention that the construction of water-works is almost sure to enhance the value of property along its lines, under its protection, and availing of its conveniences. There is, also, a perpetual reduction in the yearly rates of insurance. The substitution of soft-water for hard-water, as almost all waters are, results in a material reduction in the daily waste accompanying the preparation of foods, in laundry and cleansing operations, in the production of steam-power, and in many of the processes employed in the useful arts.

There are many industries, the introduction of which are of value to a community, that cannot be prosecuted without the use of tolerably pure and soft-water. To save the annual aggregrate of labour required to convey water from wells into and to the upper floors of city tenements or residences, is a matter of no inconsiderable importance; but paramount to all these is the value of the sanitary rsults growing out of the maintenance of health, and the inducement to cleanliness of person and habitation, by the convenience of an abundance of water delivered constantly in the household, and the enhanced safety to human life, and to property from destroying flames, accompanying a liberal distribution of public fire hydrants under adequate pressure throughout the populous districts.

709.—*Show by a table of verified statistics the effect of a pure water-supply.*

Name of Town.	Population.	Expenditure on water-supply.	Death-rate per thousand.	
			Before introduction of water.	After introduction of water.
		£		
Chester ...	39,569	74,816	30	23·3
Gildersome ...	4,000	2,000	27	16·
Hull ..	149,000	215,000	31	16·
Manchester ...	1,000,000	2,850,000	33	24·7

710.—*If called upon to report on a scheme for a proposed water-supply to a town of 90,000 people and being provided with the ordnance sheets of that part of the country, explain how you would do so without walking over the whole district.*

Ascertain the limit of the rain basin of the stream down to the points at which it was to be impounded, by levels marked in figures on the map.

If the catchment area under consideration happen to form part of some large region, whose rainfall has been thoroughly investigated, and in which numerous flood discharges have been arrived at through velocity observations and computation, some general coefficient of drainage may have been determined for that region. In that case the computation for flood discharge from any portion of it can be computed by formulæ.

1.—*If called upon to devise a scheme for water-supply to a population of 30,000 persons, what are the points to which you would specially direct your attention ?*

Ascertain as nearly as possible the present expenditure and prospective needs. If the town is entirely sewered, the flow of sewage will give an idea of the expenditure of water, the amount of ground-water in sewers being ascertained by observations taken at night, when the drains are not in use. To this must be added water used for street watering and for fires, which will perhaps not enter the sewers, but flow off by natural channels and any waste from factories passed into streams; allowance must be made for increased expenditure that will take place when dwellings hitherto supplied by wells are given a constant service, and a further allowance for prospective increase of population based upon calculation made from increase between the first and last preceding census or other mode most applicable. The rateable value of houses, the number of water-closets and baths in use, the quantity used for manufacturing purposes, will all be taken into account, in estimating the quantity required.

Possible sources of supply will next fall under consideration. What gathering-grounds are available, their nature and extent, what they will furnish, which may be estimated by gauging streams ; facilities afforded by the nature of the ground for forming storage-reservoirs in convenient situations, amount to be deducted from available total to satisfy existing water-rights, etc.

712.--*Explain with reference to population the subjects of gathering-ground, rainfall, and storage ?*

The number of people to be supplied, and the number of gallons per head required being known, area of gathering-ground required will depend upon the following factors. The mean annual rainfall, that is, the mean fall in the driest three consecutive years on record, should be ascertained ; this will generally be about five-sixth of the average rainfall. A portion of the rainfall will be lost by evaporation and absorption. This will be much the same year by year, whatever the total fall, and may be equal to a fall of 10 to 14 inches, the total fall (in England) ranging from 16 to 70 inches. (There are one or two exceptional places where the fall is considerably greater.) A further deduction from available rainfall capable of being stored, will have to be made on account of storage to compensate mill-owners and others having water-rights, perhaps to the extent of one-third or one-fourth of the available total. Capacity of storage-reservoirs will depend upon area of catchment. With a catchment area large in proportion to population and with a fairly distributed rainfall, the necessary storage space will be less than in a district where there are long droughts to be provided for, and when the catchment area small, it is essential that loss by escape of water during heavy floods should be minimised by providing large reservoirs. Average loss by overflow of storm-water may be taken at about 10 per cent. of total fall and the average proportion of rainfall available for storage at about six-tenths of the whole. Reservoirs in rainy districts should contain 120 days' supply, in dried districts 200 days' supply. Hawkesley's formula for storage is $D = \frac{1000}{F}$, D being the number of days' supply to be stored, F the mean annual rainfall (five-sixths of average). Storage capacity may vary from 25,000 to 50,000 cubic feet per acre of catchment area.

713.—*What is the construction of an ordinary public water-works?*

An ordinary public water-works consists of the following:—A large *settling reservoir* in which the gross suspended impurities subside. From this it is passed into the *filter* beds. These are brick tanks, which, in India, are usually covered. The bottoms of these filters are covered with 4 or 5 feet of sand and coarse gravel, arranged from below upwards as follows:—A layer of brick or broken stone about 6 inches or 9 inches deep, then 6 inches of gravel, and lastly a layer of sand 2½ feet. On the surface of the sand, the water is 3 feet deep.

From the filter beds, the filtered water flows to the *service reservoirs* (which are covered chambers to protect the water from sun and contamination), whence it is distributed, either by gravitation or by pumping, to the different parts of the town or municipality. The rate of filtration should not be greater than 700 gallons per square yard in the 24 hours, although this amount is often exceeded. In all modern public water-works, the plan of ultimate distribution is much the same—the laying of cast-iron pipes, or masonry channels (covered or uncovered) to convey the water either direct to the filter bed or to a settling tank, from which latter it passes to the filter bed. From these beds it proceeds by mains, sub-mains, and service pipes to streets and houses. Attached to the pipes are hydrants, waste-water meters, stop-cocks and other accessory apparatus. Once the mains are laid, then those who wish, and can afford it, have service pipes connecting the supply with their house, and, if necessary, with every room and storey of the house.

714.—*Are impounding reservoirs or outfall lakes good sources of supply?*

As a rule they are, especially if the water is collected from district mountainous regions.

715.—*If called upon to provide a water-supply to a town having a population of 20,000 persons, to what points would you direct your attention to enable you to determine the quantity necessary? And what would be the nature of the investigation which you would make in order to determine the source from which you could best obtain the supply?*

To determine the quantity necessary inquiries would be directed to ascertain what would probably be wanted for present and prospective needs under the following heads:—

(1) For domestic use.
(2) For trade and manufacturing purposes.
(3) For municipal purposes.

The quantity wanted under the first head will vary with the nature of the population. Occupiers of large houses will use more water per head for baths, washing and cleansing; the number of baths and water-closets used and likely to be brought into use with a better supply would have to be estimated.

The occupations of the working classes will affect the demand, more water for washing clothes and person will be used where people work at dirty trades.

For trade purposes inquiries as to requirements must be made of manufacturers. Large quantities may be required for gelatine factories, bleach works, tanneries, and breweries. In some cases of towns of the size named, situate near a much larger town, the local laundries may do a large proportion of the washing of such large town, and water will be wanted for this purpose.

For municipal purposes estimate the quantity required for public baths, street-watering and sewer-flushing.

The possible sources of supply are—

(1) Water from upland moors stored in a reservoir or reservoirs.
(2) Water from a deep well obtained by pumping.
(3) Water from a stream, either drawn off by gravitation or pumped.

In a scheme for providing water from high uncultivated lands, the following points have to be considered:—

Acreage of catchment basin; mean rainfull of three driest years on record; loss by percolation and evaporation and by heavy floods; provision to be made for existing water-rights, as mills, &c.

In framing a pumping scheme the geological formation of the district must be inquired into. Are there water-bearing strata below their depth, if so, their nature, and probable yield? What mineral does the water hold in solution, is it too hard for use, and is the hardness "permanent" or is it "temporary" and capable of removal?

Before fixing on a scheme of supply from a river, it must be ascertained whether it receives the sewage of towns or villages upstream, whether the water is habitually or frequently dirty from matters held in suspension, best points for taking the supply, etc.

Cost of supply from two or more possible sources should be carefully estimated both in respect of principal outlay and the interest thereon and working expenses.

The latter will be probably the heaviest in a pumping scheme, but the interest or cost of permanent works for a gravitation scheme might outweigh it.

In some favoured places water may be obtained from a mountain lake or other natural reservoir.

In seaside towns water for road-watering, sewer-flushing, and baths may be advantageously obtained from the sea.

716.—*Suppose that such data are not available, how else may the engineer place himself in possession of enough information for to proceed with his project?*

In many instances it is, from want of sufficient information, utterly impossible to obtain this perfect knowledge; in others, the deficient data may be supplied by approximative deduction from the data of other places, so that a tolerably correct approximate balance may be struck between the downfall and the amount evaporated, absorbed, and run off; in any case, however, the engineer may, with time and means at his disposal, gauge the streams and river affecting his works, and make correct records of the amount of water run off in them at different seasons of the year, and in exceptional floods. Failing, however, both time and opportunity, such data have to be observed in a rapid manner, that will enable him to determine this approximately; such as the section and fall of the rivers, the depths at various stages, flood-marks, and a few velocity observations

717.—*What are the usual methods in delivering water?*

By gravitation from an elevated impounding basin; elevation by steam or water-power to a reservoir, and from them by gravitation; elevation to low and high service reservoirs, and from thence flow by gravitation to respective districts; and by forcing with pressure direct into the distribution pipes.

718.—*Is there any other consideration in the distribution of water of importance?*

There is; the *accessibility* of a water to the people should not be forgotten. A public water-supply, situated say 400 yards from a locality, leaves its inhabitants almost *in statu quo* as to water-supply.

719.—*What are the special sources of water-supplies in Indian towns and villages?*

As special sources of water in Indian towns and villages we have:—

(1) *Wells*, superficial and deep, either public or private.
(2) *Lakes*, large and small, natural and artificial.
(3) *Rivers and streams.*
(4) *Ponds, ditches, effluent from irrigated land, and marsh water.*
(5) *Public water-works.*

In general terms it may be stated that all of these waters except (5) are more or less impure, and that without previous boiling and filtration of their waters, are unfit to use for drinking purposes. All are subject to various forms of pollution.

720.—*What is the maximum demand of water in towns in relation to the average demand?*

As 2½ : 1, or two and a half times the average hourly demand in a day of 24 hours.

721.—*What follows from the fact that the greatest hourly demand for water is more than double the average hourly demand?*

That the main conduits supplying a town must have double the discharging power that would be required, supposing the demand were uniform. The first requisite of a supply of water is that it should be abundant, and sufficient in amount for any extra strain on its capacities. [Water ought to be laid on to every house, and to at least two floors of the house. Anything preventing free access to water, militates against cleanliness.]

722.—*What are the different sources of water usually available for town supply? State the advantages and disadvantages of each with reference to health, and what amount per head is generally considered necessary?*

Rivers, streams, natural springs, artificially-formed wells, and impounding reservoirs or a combination of any of the former. In river-supply the advantages consist in its constancy, ease with which it can be collected for filtration and its general softness; at the same time this is greatly counterbalanced by its liability to contamination and often costly pumping. Natural springs are generally pure, and often so placed as to admit of a gravitation supply (a great feature in a water-supply), though sometimes the water is hard; their disadvantages is their liability to give out in seasons of drought. Artificially-formed wells, if carried down to a good water-yielding strata, are undoubtedly the most pure source of water-supply. Of course the greatest care must be taken both in the construction of the well itself and in the selection of the site, as a well may often be formed to yield a good supply for some time.

723.—*What should be considered an abundant supply of water?*

This is a question which does not admit of answer from simple theoretical considerations. We may determine with tolerable accuracy the amount necessary, or the average, for each family for household purposes, on the amount required in certain manufacturing establishments for a given amount of finished product; but for many purposes it is very difficult to estimate, and the item of waste enters largely into the account.

724.—*With regard to the chosen sources of supply should it be capable if necessary of providing a much larger quantity of water than the ordinary supply?*

The chosen source must be able, on occasion, to furnish an very greatly in excess of the average consumption.

.—*What is the best force to use in water-supplies?*

Gravitation. When a good and abundant supply of water can be gathered at a sufficient elevation, and within an accessible distance, the essential element of continuous full-pressure delivery can then most certainly be secured, and in the matter of possible safety the gravitation method will usually be superior to all others.

The value and importance of sufficient elevation of the supplying reservoir, when the delivery is by gravity, to meet the most pressing needs of the fire-service is usually one of the chief objects to be attained in a complete water-supply.

726.—*In a perfect supply what force is used?*

Gravitation only. The supply should be at such a height that the force of gravitation alone is enough to throw sufficient water 20 feet above the highest house.

This only by having a sufficient number of hydrants would do any good with a fire. The source of supply in gravitation works is the rainfall upon the gathering-ground or catchment basin, a tract of land more or less completely bounded by ridge lines, or more properly watershed lines. This latter distinction is necessary, because the hydrographical basin is not necessarily commensurate with that traced from surface contours. Valleys of denudation on an anticlinal axis, for instance, where permeable strata are superimposed, would show from surface contours a gathering-ground larger than the drainage area really available for the impounding of water, and *vice versâ*. In impervious or rocky districts the case is simplified to one of surface observations.

727.—*What has been said against such a mode of supply?*

The great pressure causing the bursting of the reservoir has occurred in Sheffield, and more lately in Hughestown, Chicago. [With good engineering the risk from this is very small.]

728.—*What are the terms used in connection with the preliminary survey for a water-supply reservoir?*

Contour lines are often formed by the subsidence of water in a lake, as in the case of the parallel roads of Glen Roy. By the use of these lines, we may show the *water-shed* of a district on a map. The term *water-shed* is used to denote the slope along which the water flows to form a river or lake; and *water-parting*, the summit of the slope. The summit of the Cotterswold Hills thus forms the *water-parting* between the *water-sheds* of the Thames and Severn. The "*crest of the water-shed*," or "*the summit of drainage*," may [illegible] be used for "*the water-parting*."*

9.—*What are contour lines?*

Contour lines are lines of equal altitude, and are what would represent the waters' edge, supposing water to stand at the various levels marked out by the figures. [The contour lines marked out in the 6th ordnance map are drawn at every 25 feet (vertical) of elevation apart, and these lines may be taken as the basin. But for purposes of water-supply, or drainage, contour lines require to be drawn closer than this; they are usually drawn for local purposes every 8 or 10 feet of elevation apart. In the ordnance maps are seen a number of dots usually following the lines of the main roads, with figures upon them: these lines express in feet and decimals of a foot the heights of the ground at various places mentioned: thus, B. M. 355·2 means that the particular spot is 355·2 feet above the ordnance datum, and the ordnance datum level for Great Britain is the level of the mean tide at Liverpool as ascertained by a series of observations taken by the Ordnance Survey in 1844: it is 8 feet below the general mean level of the ocean around the coast of Great Britain. If the place indicated by any of these figures be visited, there will be found a broad arrow marked on some prominent object, such as a milestone, or a church, or rock, etc.]

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* WHITELEGGE'S *Hygiene and Public Health*.

730.—*In surveying a catchment area for the purpose of supplying a town with water through public water-works what are necessary?*

A plan is necessary showing by means of contour lines, the undulations and general slopes of the ground.

731.—*What are ridge lines?*

They are water-shed lines, or lines which along the whole of their course, are higher than the ground immediately on each side, hence the ground slopes downwards from them at both sides.

732.—*What is a catchment area?*

A catchment area, drainage or gathering-ground or catchment basin, is a district enclosed by a ridge line which line is continuous except where the water finds an outlet. The ridge line usually gives off branch ridge lines thus producing secondary or subsidiary catchment areas, each drained by its own stream into the main stream. [The details connected with such an area are obtained from a series of levels, and the drawing of contour lines as above described.]

If lines be drawn through the sources of the tributaries of rivers marked on a map, they will be found to form the boundaries of certain areas which are called the catchment basins of various rivers; that is, the areas which receive the rainfall supplying their waters. In compact formations, where most of the rain runs off the surface, the ridge lines bounding these basins usually pass along the most elevated regions, but in porous formations their course will depend on the configuration of the relative sub-stratum.

733.—*What else is to be known in regard to geographical and geological knowledge of catchment areas?*

A geographical and geological knowledge of the catchment area, whose rainfall affects the works, is also needful, the boundaries of this area, its lines of water-shed and drainage, its disposition as regards prevailing winds, the nature and porosity of its soil, and the amount of vegetation or cultivation on it, as well as any available records from which the quantities of water actually run off by its streams and river in various seasons may be arrived at, are all data necessary for establishing satisfactorily a perfect knowledge of the disposal of the whole of the rainfall under any circumstances.

[illegible].—*By what formula may we get an approximation of the quantity of water from a catchment area?*

By the formula

$Q = 62{\cdot}15\ A\ (4\ R - E)$.

Where Q = the supply in gallons daily.
A = the catchment area in acres.
R = the annual rainfall in inches.
E = the loss from evaporation in inches.

735.—*What is meant by Levelling?*

It is that branch of Surveying which determines the inequalities of the earth's surface, and ascertains the relative heights of places above a certain line called the *datum* line, from the centre of the earth. (See answer No. 731.)

736.—*What may be assumed as to downpour if the catchment area is not large?*

If the catchment area is not very large, that is, not exceeding 400 square miles, or 100 square leagues, it may sometimes be assumed that the whole of it is simultaneously subject to the same amount of maximum downpour, and that the loss by absorption and evaporation is also tolerably uniform over the whole. If then some trustworthy data for this loss should be available, the flood discharge can be computed.

737.—*The catchment area of a water-supply district being* 10 *acres and the annual rainfall* 30 *inches, but after deduction of* 14 *inches for loss by evaporation, absorption, etc., we have a depth of water equal to* 16 *inches, available for domestic purposes, how much water does the whole area yield in one year, and how many persons would this provide for, allowing* 25 *gallons per day for each?*

One square acre is equal to 4,840 square yards, and therefore 10 acres equal to 48,400 square yards. This multiplied by 9 and then by 144 gives the superficial capacity of the reservoir as 62,726,400 square inches. To reduce this to cubic contents multiply by the depth, 16 inches, which gives 1,003,622,416 cubic inches. To bring cubic inches to gallons, multiply by 40 and divide by 11,091, or multiply at once by ·003607. Therefore, 1,003,622,416 [illegible] gallons is the quantity of water yielded in one year. The other method gives 3,620,065. [These are the formulæ given in PARKES' "*Practical Hygiene,*" 5th edition, note to page 8; but a handier method would be to multiply the square feet by 1⅓ (equal to 16 inches) and the product by 6¼, being the number of cubic feet in a gallon. This gives 1,630,000 gallons. Another method, which gives a still closer approximate, is to multiply the cubic feet by ·52, which gives 3,624,192 gallons.]

To ascertain how many persons this would provide for, allowing 25 gallons per day for each. 3,619,592 ÷ 365 ÷ 25 = 397 persons.

738.—*What are the most advantageous gathering-grounds?*

Mountain districts of clay-slate and granite form the most advantageous gathering-grounds, but in these cases the water generally has to pass through portions of peaty or boggy ground before it reaches the reservoir, and although the water may not be unwholesome in its natural state, it undoubtedly does become so when stored or allowed to stagnate in tanks or reservoirs; and such water has a disagreeable colour, and one that is difficult to remove.

739.—*Explain with reference to population, the subjects of* (1) *gathering-ground rainfall, and storage; and* (2), *describe the relation existing in a sewer between gradient, volume, velocity, and size.*

(1) *Water-supply.*—Number of population × gallons per head per day × number of days' supply to be stored × 6·24 = capacity of reservoir in cubic feet, allowance being made for percolation and evaporation.

Rainfall over a given area during the driest years, less loss by percolation and evaporation in transit to reservoir, and deducting an allowance for existing water-rights and another for unavoidable loss by overflow during storms, gives nett quantity to be counted on as available for storage from given unit of area of gathering-ground. Every one of these factors varies widely with circumstances.

(2) *Sewerage.*—

Let V = velocity in feet per minute.
H = hydraulic mean depth.

$$= \frac{\text{Volume or area of cross-section of stream in ft.}}{\text{Length of bed of stream.}}$$

F = gradient or fall of stream in fall in feet per mile.

Then

$V^2 = 55\sqrt{HF}$ or $V = 55^2 HF$ (squaring both sides of equation);

Transposing factors—

$H = \frac{V^2}{\text{[illegible]}}$ and $F - V^2$

Assume, or take from actual practice numerical values in place of any two of the three symbols V F H, and obtain the third by arithmetical calculation. [Work this out with variation in a few cases, backwards and forwards, to obtain a thorough grasp of the subject, and to understand that what is true generally, as stated by symbols, applies specially in any given case.*]

740.—*Upon what does the amount of rain that can be utilised for supply depend?*

As all water-supply comes either directly or indirectly from the rain, the amount of rain which can be utilised for the supply of a town, depends upon the rainfall and the catchment area.

741.—*Mention an excellent water-supply from a natural lake.*

That of Glasgow from 34 miles to the north of the city. It contains only $2\frac{1}{2}$ grains of matter per gallon, of which about one-half is organic (peat), the rest being mineral. It has a faint yellow colour.

742.—*What advantage has this been to the city of Glasgow?*

Established in 1859, it replaced the foul water-supply from the river Clyde. It increased the health of the people, and caused a great saving of money in manufactures and industries from the fact of there being but one grain of mineral matter per gallon instead of several. The saving in soap alone has been £36,000 per annum.

743.—*Discuss the question of permanency of supply.*

It is obvious that the permanence of the supply of a spring or small stream may often be of the greatest moment in the case of an encampment, or in the establishment of a permanent station.

In the first place, evidence should, when available, be obtained. If no evidence can be got, and if the amount and period of rain be not known, it is almost impossible to arrive at any safe conclusion. The country which forms the gathering-ground for the springs or river should be considered. If there be an extensive background of hills, the springs towards the foot of the hills will probably be permanent. In a flat country the permanency is doubtful, unless there be some evidence from the temperature of the spring that the water comes from some depth. In limestone regions springs are often fed from subterranean reservoirs, caused by the gradual solution of the rocks by the water charged with carbonic acid; and such springs are very permanent. In the chalk districts there are few springs or streams, on account of the porosity of the soil, unless at the point the level be considerably below that of the country generally. The same may be said of the sandstone formations, both old and new; but deep wells in the sandstone often yield largely, as the permeable rocks form a vast reservoir. In the granitic and trap districts small streams are liable to great variations, unless fed from lakes; springs are more permanent when they exist, being perhaps fed from large collections or lochs.†

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* *Sanitary Record*, 1868.

† PARKES' *Practical Hygiene*, 7th Ed.

744.—*What precaution is necessary in regard to the introduction of a public water-supply from regions possessing metallic mines, and from certain mountainous districts?*

The water of certain metallic and mountainous districts, especially where metals abound, should be carefully searched for metals if it is intended to use the water for a public water-works, for filtration does not completely remove metals, as it may do, if thoroughly efficient in the case of organic matter and salts.

745.—*State briefly the qualities desirable in a supply of water for a community.*

The conclusions thus far reached are that a suitable source of supply should furnish water which is abundant in quantity; the water should be colorless and clear, *i.e.*, free from all turbidity; it should be soft and contain not too large an amount of mineral matter in solution; it should contain no excremental or other animal matter; and it should be so situated as to make it possible to protect it from defilement in the future. Moreover, while the imagination as well as the reason is to be consulted in the choice of a supply, an extravagant outlay is not justified when called for by extravagant demands for excellence.

746.—*What is meant by double supply?*

In view of the difficulty which sometimes exists, of obtaining from a single source a sufficiently abundant supply of good water to meet all the wants of a large community, it has often been proposed to adopt a system of double supply, *i.e.*, to furnish water of two qualities. It is true that for many purposes, as for extinguishing fires and for sprinkling streets, for closets, drains and sewers a water would answer which would not be suitable for drinking, and such a supply might in many cases be easily procured, while to procure an abundance of water well-suited for drinking would involve a large outlay. To the double system there is no objection, if the poorer water can be drawn only from street-hydrants, which are under municipal control; but it is not practicable to supply two sorts of water to private dwellings, with any security that the distinction between them will be regarded; no domestic, and indeed no average inhabitant, will fail to use for all purposes that water which is most handily obtained, unless, indeed, it be actually repulsive to the taste. In the case of large cities, it is seldom that a single source of sufficient size can be found, and it becomes a question to be settled by local considerations whether each portion of the supply shall be distributed to a different section of the city, or whether the water from all sources shall be united in a common reservoir or reservoirs, and distributed therefrom.

So long as the impure supply is under control, and is limited to public and trade purposes, no objections can be raised, except on the score of the cost of distributing a double supply. But for household use a double supply must be deprecated. In a house the supply which is most copious and easily accessible will generally be used by preference, except the impure supply be foul to the senses. Common household experience shows that servants, even of the better class, will, when two taps are side by side, draw water from that which delivers water most freely (generally that from a cistern, where one tap delivers from the main and the other from a cistern). In this respect the majority of people cannot be trusted to make a choice. A double supply for household use ought not to be adopted, except for very cogent reasons.

suggestion has arisen out of this circumstance?

A double supply was proposed from London in 1878 by the Metropolitan Board of Works—the permanent river-supply for general purposes, and a deep chalk water-supply for drinking purposes.

748.—*Why did such a scheme fall through?*

Increase of the expenses of a double source of supply, and the danger that the impure water would through carelessness or ignorance, be often used for drinking purposes when it happened to be nearest at hand.

749.—*Is it easier or more difficult to manage a proper water-supply in a rural district than in a town?*

Rural sanitary districts contain many aggregations of population of 2,000, 3,000, and 5,000; and it is these places which are the most difficult to deal with in respect of the water-supply. Take, for instance, one parish of, say 4,000 population, in a dozen parishes constituting the rural sanitary district of, say 20,000 or 30,000 population, living on about as many acres of ground; three-fourths of the population of the parish may be congregated on 100 acres, the other thousand being distributed in something like the following manner;—100 at A, 200 at B, 300 at C, and 400 at D. Now, leaving out of the question how three-fourths of the population of the parish may be supplied, those designated A, B, C, and D, will probably all procure water for domestic purposes from sources liable to contamination from passing persons and animals, whether accidental or wilful. But supposing a satisfactory water-supply to be arranged for the main portion (say the 3,000) of the population, it would probably not pay, at the current water-rate, to supply the small outlying places—the other fourth; although, living within the same sanitary district, they may very properly say they have the right to be supplied equally with those who live more centrally in the same district, providing they are willing to pay the current water-rate on the value of the house. But if the sanitary authority must include these outside people, the water-rate upon those more centrally situated must be increased, so that an average rate may be struck for the whole district. It is therefore advisable to protect and render as useful as possible all the small sources of water in the outlying parts so that the inhabitants may procure, in a tolerably pure state, whatever quantity these small sources yield.

750.—*In projecting artesian wells for town-supply is it important to know the geological character of the locality where the boring is to be made?*

It is most important to ascertain this and, as far as possible, the source of the water. Indeed, without a knowledge of the probable character of the particular locality, sinking an artesian well is like investing in a lottery, and hardly justifiable as a municipal undertaking. It is true that many wells are sunk without the advice of competent authority, and some of them are successful; as a rule, however, they end in failure. The instance of the St. Louis well where 810,000 dollars were sunk in the well, is instructive in this connection.

751.—*Suppose we have a well in which the water rises just to the surface of the ground, but does not overflow, and that if 100 gallons per minute be pumped regularly, how much is the water-level lowered?*

A distance of five feet.

752.—*What are the sources of public water-supply? In addition to deep wells, from what sources may water-works on an extensive scale obtain their supply?*

From lakes, streams, rivers, or gathering-grounds. [If from a lake of sufficient elevation above the level of the town to be supplied, the water may be distributed throughout the town in conduits and pipes by the force of gravity. When the source of supply is a stream or small river storage works are necessary; but when the river is large, a constant supply can be obtained at all times, independently of storage. In this case the works required usually comprise—a weir or dam for maintaining part of the river at a nearly constant level; two or more settling ponds, into which the water is conducted: filtering apparatus, and pumping engines.]

753.—*What are sources of London water-supply?*

Thames, New River, river Lea, river Ravensbourn, deep wells, and shallow wells.

754.—*What is the most favorable situation for a gathering-well or gallery?*

In the neighbourhood of a river (or lake), for two reasons: first, because at such a place there is almost certain to be a decided movement of the ground-water toward the stream, and, in the second place, the water from the river can make up any deficiency caused by removal of the ground-water, by filtering through the bank and bed of the river. For these reasons, the locality most commonly chosen is on the bank of a running stream in a deposit of gravel. The simplest form of collecting works is the open basin;

but in an open basin the water is exposed to the direct rays of the sun, and, in summer, becomes heated above its natural temperature.

755.—*Name another method of utilizing the ground-water?*

That of constructing a covered gallery which shall permit the percolation of water into it and from which the water can flow to the pump-well; for, as is indeed ordinarily the case, when supply is taken from rivers, pumping-works are almost always a necessary part of such a scheme. Sometimes the collecting galleries or pipes are, as in the instance just mentioned, placed actually beneath the bed of a river or pond.

"The water is obtained from a gravel or sand bed which lies within the bed of the river when the water is high, although not covered with water for the greater part of the year. In this gravel-bed a trench of 250 feet long was dug of such depth as to bring the bottom of it as low as, or lower than, the bottom of the river at its deepest part, and of 6 feet or more in width. The trench was then filled to the depth of a foot with stones of various sizes, from small cobble to coarsest gravel stones, making the surface as even as possible, though with a slight grade down-stream.

"On this foundation a line of timbers 6 by 6 inches is laid on each side of the trench, 4 feet apart. Across these are placed and firmly nailed on, 3 feet apart, square frames 4 feet wide by 3 feet high, made of timber 6 by 6 inches, each frame strengthened in the centre by a standard 2½ by 6 inches from the top to the bottom. The top and two sides of this row of frames are covered with hemlock plank 2½ inches thick, and thus a filtering-gallery 250 feet long, 3 feet high, and 4 feet wide, is made."

On the outside of this gallery, at the bottom, a filling of 8 inches of excelsior is lightly tamped down, and then the trench is filled up with the gravel, and the filter is complete. From this filter 600 gallons per minute of the clearest water are obtained. The filtration is upward and through the stone bottom! the gallery is kept full in low water by taking water through canals over the filter from a point in the river above.

[Another method of collecting the ground-work consists in employing, instead of such a gallery as has been described, a line of iron pipes, *i.e.*, practically water-mains, cast with a great number of narrow longitudinal slits, and laid with loose joints. These pipes collect the water, and conduct it to receiving-wells, from which the supply is pumped. In filling the trench in which the pipes are laid, the pipes are surrounded on all sides with coarse material of too large a size to fall into or through the slits, and the trench is then filled with screened material of decreasing size. The figure (Fig. 12) will give some idea of this method. A less elaborate mode of applying the same principle consists in substituting for the iron pipes ordinary cement or other unglazed drain-pipes, laid loosely.

At Arlington, Mass., such an arrangement is in operation, the pipes being laid in the gravelly bed of an artificial reservoir, made by damming a small brook.]

756.—*Why is this source called ground-water and not a method of natural filtration?*

In the first place, the general facts with reference to the ground-water which have been stated, as well as others (already mentioned) lead to this conclusion; in the second place, the temperature of the water in the well or gallery differs from that in the river, being higher in winter and lower in summer, and varying within narrow limits, unless the water is received in an open basin and exposed in a comparatively shallow surface to the atmosphere; in the third place, the water in the well generally differs in a marked degree in the character or amount of the dissolved substances.

757.—*What is the first consideration of a good water-supply?*

Efficiency. This necessary condition is common to all classes of machines and is of primary importance in all. Until very recently, pumps have been from this point of view, the most unsatisfactory of mechanical appliances. It has been stated on good authority that previous to the International Exhibition of 1857, no pump ever attained an efficiency of 40 per cent., and that many returned no more than 10 per cent. of the force expended in water raised. Since that time, however, the attention of Engineers has been directed to the subject, and such improvement of design and construction have been effected that this enormous loss of power has been reduced, in average cases, by at least one-half. So far this is a very satisfactory result. But there yet remains much to be done before that degree of perfection is reached to which other kinds of machinery have been carried. The large proportion of the motive power absorbed by the organs of transmission and the loss of water through the valves still leave much to be desired.

In determining what is due efficiency regard must be had to the character of the work and also to the conditions under which it is performed. A pump for draining a mine for instance may return in water raised 10 per cent. less than another pump applied to the draining of a surface, and yet the former may be a more satisfactory machine than the latter. Thus, due efficiency must be considered relatively, not absolutely.

758.—*In framing a pumping scheme of water-supply what points have to be considered?*

In framing a pumping scheme the geological formation of the district must be inquired into. Are their water-bearing strata below, if so, their depth, nature, and probable yield? What minerals does the water hold in solution, is it too hard for use, and is the hardness "permanent," or is it "temporary" and capable of removal?

Before fixing on a scheme of supply from a river, it must be ascertained whether it receives the sewage of towns or villages upstream; whether the water is habitually or frequently dirty from matters held in suspension, best point for taking the supply, etc.

Cost of supply from two or more possible sources would be carefully estimated both in respect of principal outlay and the interest thereon, and working expenses.

The latter will be probably the heaviest in a pumping scheme, but the interest or cost of permanent works for a gravitation scheme might outweigh it.

759.—*A small district in the country, composed of 20 colliers' houses, is without proper water-supply. What steps can be taken under the Public Health Act in order to obtain a supply? What are the duties of the local authority in such circumstances (1) as to discharging their own responsibilities, and (2) as to compelling the owner to adopt certain measures?*

The 89th Section of the Public Health Act provides that upon requisition to that effect made by not fewer than ten inhabitants of the district, whether rate-payers or not, the local authority shall be bound to meet, after 21 clear days' notice, and consider the propriety of forming part of their district into a special water-supply district, and the resolution of the local authority shall be published in the newspapers. It is competent for any person within 10 days to appeal to the sheriff, who is authorised to determine the question and define the limits of the district if necessary.

After a water-supply has been provided in a district the local authority can compel owners to provide the same to any house within the district which is without a proper supply of water at or near the same. The question of distance from the house in case of dispute is one for the sheriff to decide

760.—*What other works of public benefit should be associated with*

Public baths which should be erected and freely supplied with water, which should, if possible, be kept constantly flowing in and out.

761.—*What should the plan of distribution of water include?*

The plans for the distribution of water should include arrangements for the easy and immediate removal of dirty water. This is an essential point, for in many towns where houses are not properly arranged for small families, there are no means of getting rid of water from the upper rooms, and this inconvenience actually limits the use of water, even when its supply is ample.

762.—*What points may be adduced in favour of the total abolishment of wells when a better water-supply is available?*

(1) In drawing water from wells, there is great expenditure of time and labour, in consequence of which

(2) an insufficiency will be drawn and used, and as a secondary result, there is bound to be

(3) defective domestic cleanliness with all its accompanying evils. There appears to be a fixed ruling on the part of the people, that the quantity of water used decreases as the labour expended in procuring it increases; and conversely where facilities for providing it are great, the consumption is large.

[We have proved, from special observations made on the subject, that the ordinary *bustee* occupant does not use more than two gallons of water a day (unless the well is at his very door), a quantity altogether inadequate to effect the least semblance to domestic or personal cleanliness.

Let us attempt to put the matter a little more clearly. To enable perfect cleanliness to be carried out in a household with the average number (about six) of people in it, each person requires about 12 gallons per day, that is, 72 gallons has to be daily conveyed to the house. Say the average distance of the well is 50 yards (many are 200 or 300 yards off) and the depth of the well 30 feet.

One gallon of water weighs 10 lbs.; 72 gallons, 720 lbs., which raised 30 feet=21,600 lbs. The same carried 50 yards or 150 feet=108,000 lbs., or about 48 foot tons, in all, there being about 60 foot tons of labour expended. Modern public water-works aim at altering this by providing water at the doors of the inhabitants.]

763.—*In order to secure an adequate supply of pure rain-water for domestic purposes, at dairy farms and country residences, what methods of collection, storage, etc., would you recommend?*

As to the methods of collection there are two simple methods; (1) that of the eaves, gutters, and conductors leading to concrete reservoirs clear of the building, and in a position not near drains, dung-heaps, or other impurities. The eaves, gutters and conducting pipes are too often formed of iron. The softeness, however, of rain-water has the effect of dissolving these metals, and lead and iron are therefore objectionable, if not dangerous. The jointing of conductors, eaves and gutters should be so formed that all the water be collected, they should also be clear of all sewers, drains, etc. The water should pass through sand and charcoal filters in order to remove the suspended and organic matter. The first part of the rainfall should be allowed to run to the drain. (2) Shallow reservoirs constructed some distance from the house, and formed of concrete, have also been recommended by sanitary engineers, as obviating the roof impurities of the houses. They should be fenced in from cattle or other animals. Concrete tanks should be aërated, riodically cleansed, and be provided with a man-hole and sludge-ok. [One inch of rain delivers 4·673 gallons on every square yard, 22,617 gallons, weighing 101 tons on each square acre.]

764.—*A town requires* 30,000 *gallons of water a day. What should be the size of the reservoirs to contain a three days' supply?*

$\frac{30,000}{6·24 \text{ (gallons in a cubic foot)}}$ = 4,800 cubic feet (approximately), which is the amount required daily, and which multiplied by 3, equals the amount of a three days' supply, and therefore the requisite *available* capacity of the reservoirs.

765.—*To what is the Chemical Examination of a ground-water proposed for town-supply, mainly directed?*

To ascertaining the organic matter or to the evidence of previous pollution, but does not differ essentially from that followed out in the case of shallow wells It should be accompanied by an examination of the stream or pond. if the water is to be taken in the neighbourhood of a visible body of water, although, as we have seen, it is generally the case that the stream contributes a relatively small volume of the supply.

766.—*Is the Thames likely to ever fail in giving a sufficient supply of water to London?*

The opinion expressed by the Royal Commission that investigated this question is as follows:—

That the river Thames, supplemented if necessary by works for storing the flood waters, together with the river Lea and the water obtainable from the chalk from the south and south-east of London, as well, probably, from the lower Greensand, will furnish a supply sufficient for any probable increase of the Metropolitan population. That a probable increase of population to 4,500,000 or 5,000,000, may have to be provided for.

767.—*What is a Store Reservoir and what are the purposes it serves?*

A store reservoir is a place for storing water, by retaining the excess of rainfall in times of flood, and letting it off by degrees in times of drought. They are used for one or more of the following purposes:—

To prevent damage by floods to the country below the reservoir; to prevent the evil consequences of droughts; to increase the ordinary or available flow of a stream by adding to it the whole or part of the flood water; to enable water to be diverted from a stream without diminishing the average monsoon flow; and to allow mechanical impurities to settle.

768.—*Define what is meant by an impounding reservoir?*

It is a reservoir of water formed by constructing a dam across a valley through which a stream runs, thus creating an artificial lake.

769.—*Name such a reservoir, in existence?*

That at the Moorfoot Hills near Edinburgh.

770.—*What is usually the best site for a reservoir?*

Where there is an embankment thrown across a narrow gorge: this will usually embank a large basin.

771.—*In regard to the size of the reservoir what general principle may be laid down?*

It can scarcely be too large, for the larger it is the longer the time during which repairs may be carried on without interrupting the service; its capacity will be determined by the facilities which we have for its construction and the fluctuations to which the supply is liable, and we have to determine upon a minimum. The same may also be said of the height and the depth; the overflow cannot be too high, nor the bottom too low. The height will be limited either by the level of the source or the power of the engine, and the depth must be such that it will still be able to supply the highest orifices when the water has descended nearly to the bottom.

The reservoir itself is generally a natural hollow, situated in the valley-line of the catchment basin, and of sufficient elevation to procure a fall, so that the water can be distributed without mechanical means being required to raise it.

In India the storage tank should be large enough to contain a 12 months' supply; and the site which can supply the requisite storage-room with the least embankment and the least area laid under water is to be preferred.

Loch Katrine is a natural reservoir or lake, and Lake Thirlmere, from which Manchester receives its new water-supply, is also a similar lake, which is to be increased in capacity, and its level raised fifty feet, by a dam built across one end of it. The natural outlet of Lake Thirlmere is to the north, but the water for Manchester is to be obtained by tapping the southern end of the lake, and drawing off the necessary quantity of water by means of a tunnel through Kirkdale Pass. [As a rule they are constructed either by excavation or embanking, the simplest plan being to carry an embankment across a valley. A lining on concrete or clay puddle may be needed to render them water-tight. The embankments, necessarily of great strength, have a core of clay puddle and are protected from disintegration by a covering of grass on the outer side and dressed stone on the inner.]

772.—*How may we determine the site of a reservoir?*

By observing the features of the ground, and the elevation. It

must be high enough to distribute the water when nearly empty, and low enough to allow of a sufficient gathering-ground above its highest level. (See next No.)

773.—*What are the points to be considered in selecting sites for reservoir?*

In choosing the site of a reservoir, the engineer has chiefly three things to consider: the elevation of the site, the configuration of the surrounding country, and the materials for the work, especially those materials which will form the foundations of the embankment, or embankments, by which the water is to be retained.

The *elevation* of the site must at once be so high, that from the lowest water-level there shall be sufficient fall for the pipes, conduits, or other channels by which the water is to be discharged to reach the highest point over which the water has to be conveyed, and at the same time so low that there shall be a sufficient gathering-ground above the highest water-level.

The *configuration* of the ground is of great importance. That best suited for a reservoir site is that in which a large basin can be enclosed by embanking across a narrow gorge. To enable the engineer to compare such sites with each other, and to calculate their capacities, plans with frequent contour lines are very useful, or in the absence of contour lines, numerous cross sections of the valleys. Of course the water's edge of a reservoir would itself be a contour line.

As these large artificial reservoirs are generally made on the natural surface of the ground, and bounded in one direction only by an embankment of earth or a dam of masonry or brickwork, the first object is to choose a site or sites where the greatest amount of water can be stored with the shortest and least amount and length of embankment; for this purpose a river gorge, narrow and precipitous, terminating a great length of country, having a gradual fall towards it, offers the best ordinary natural conditions; if in addition, the lateral or transverse slope of the country is also very gradual, it becomes a large natural basin, with one narrow outlet, and if this admits of being easily dammed, an extraordinary advantage not often available presents itself.

Much care is necessary in selecting *ground* for the construction of a tank for drinking-water. The interior of towns and villages is to be avoided, for the soil of such places has been impregnated with the impurities resulting from the percolation of filth and drainage for years. "Made soil" is likewise specially objectionable as a site for a tank. The vicinity of all filthy pools and ponds is also to be avoided, for they will feed the tank through the medium of the subsoil. This may of course be prevented by having a thoroughly well rammed puddle bottom, and constructing an embankment, the core of which should be puddled. All this however, increases the initial expense, and a puddled bottom is not always effectual in preventing percolation from the subsoil. The inside of the embankment of tanks should be constructed of masonry, and the outer face turfed. No trees or shrubs should be allowed to grow on the embankment, for the roots sink into, and spilt up the core, causing leakage and the formation of rat holes. A new tank should always be dug in new ground, and any foul ponds, cesspits, or superficial wells close by should be filled with earth. The earth dug from the tank will be valuable for this purpose. Tanks are fed by natural water channels leading to them, by specially constructed channels from impounding reservoirs or by similar channels without such reservoirs. In some cases tanks form the catchment basin of a large area of ground, specially prepared or not, to receive the water.

774.—*After choosing a site for a reservoir, what is the first point to attend to?*

The determination of its storage capacity up to different proposed levels of escape. For this purpose, marks are fixed at differences of level of about 5 or 10 feet, on any convenient short line of section, and the contours of these levels are marked out and surveyed around the basin, in order to obtain the perimeters and areas at each contour, from these the contents of each lamina can be calculated, and the content up to any other contour. If however it be preferred to obtain this by means of a series of longitudinal and transverse sections taken up to the heights of the various contour levels, it is perhaps best to direct the former in conformity with the axis or axes of figure of the basin, and the transverse sections at right angles to them, and as far as possible at equal distances along them, although in some instances, unequal distances and inclined directions, more suited to the form and disposition of the ground, would give more correct results, the true values of the corresponding rectangular transverse sections can then be obtained from the oblique sectional areas by multiplying them by the co-sines of their angles of obliquity. Should a winding river channel or depression form part of the basin, it is often more convenient and correct to estimate its content independently and add it in afterwards.

775.—*After fixing the site and determining the storage capacity of the reservoir, what is next to be done?*

After the site of a reservoir has been fixed, a plan of it should be prepared, with contour-lines numerous and close enough to enable the engineer to compute the capacity of all parts of the reservoir from the lowest to the highest water-level, so that when the reservoir is constructed and in use, the inspection of a vertical scale fixed in it may show how much water there is in store.

Care should be taken to observe whether the basin of a projected reservoir site has, besides its lowest outlet, higher outlets through which the water may escape when the lowest outlet is closed, unless they also are closed by embankments.

776.—*What precautions are to be taken with regard to the figure of ground at the site of a proposed reservoir embankment?*

It must be determined with care and accuracy, by making, not only a longitudinal section along the centre line of the embankment, but several cross-sections of the site of the embankment, which should be at right angles to the logitudinal section, unless there is some special reason for placing them otherwise. One of these cross-sections of the embankment site should run along the course of the existing outlet of the reservoir site, which is usually a stream, and another along the course of the intended outlet.

777.—*What points are to be attended to in the construction of the foundation of the embankment of the reservoir?*

The soil of the site of the intended embankment should be impervious to water, or capable of being easily removed so far as it is pervious, in order to leave a water-tight foundation; and its nature is to be ascertained by borings and trial pits. In some cases it is not sufficient to confine this examination to the site of the embankment; but the bottom and sides of the reservoir-basin must also be examined, in order to ascertain whether they do not contain the out-crop of porous strata, which may conduct away the impounded water. The best material for the foundation of a reservoir embankment is clay, and the next, compact rock free from fissures. Springs rising under the base of the embankment are to be carefully avoided.

The engineer should ascertain where earth is to be found suitable for making the embankment, and especially clay fit for puddle.

778.—*What are the points concerned in the construction of the reservoir embankment?*

The embankment is to be made of clay in thin horizontal layers. The central part of the embankment should be a "puddle wall" of a thickness at the base equal to about one-third of its height; it may diminish to about two-thirds or one-half of that thickness at the top. Great care must be taken that the puddle wall makes a perfectly water-tight joint with the ground throughout the whole of its course, and also with the puddle coating of the culvert.

During the construction of a reservoir embankment, care should be taken to provide a temporary outlet for the water of its gathering-ground, sufficient to carry away the greatest flood discharge. This may be done either by having a pipe sufficient for the purpose traversing the culvert, or by completing a sufficient bye-wash before the embankment is commenced.

The outer slope is usually protected from the weather by being covered with sods of grass. The inner slope is usually pitched or faced with dry stone set on edge by hand about a foot thick up to about three feet above the top water-level, and as much higher as waves and spray are found to rise. The top of the embankment may be covered with sods like the outer slope; but it is often convenient to make a roadway upon it. In either case it should be dressed so as to have a slight convexity in the middle, like that given to ordinary roads, in order that water may run off it readily.

No trees or shrubs should be allowed to grow on a reservoir embankment, as their roots pierce it and make openings for the penetration of water. For the same reason no stakes should be driven into it.

779.—*What should be the general figure and dimensions of the reservoir embankment?*

A reservoir embankment rises at least 3 feet above the top water-level, and in some cases 4, 6, or even 10 feet. It has a level top, whose breadth may in ordinary cases be about one-third of the greatest height of the embankment; the outer slope, or that furthest from the water, may have an inclination regulated by the stability of the material, such as 1½ to 1, or 2 to 1, the inner slope or that next the water is always made flatter, its most common inclination being 3 to 1.

780.—*What is the usual height of the embankment?*

The height of the embankment varies from 3 to 10 feet above the highest water-level, the top being covered with broken stones.

781.—*What is the Bye-Wash?*

The bye-wash is a channel sometimes used to divert past the reservoir the waters of the streams which supply it, when these are turbid, or otherwise impure. Its course usually lies near one margin of the reservoir, and is then conveniently situated.

782.—*With what is every impounding reservoir provided?*

With an *overflow weir.*

783.—*What functions does this subserve?*

It permits the discharge of the flood-supply from the drainage area, and this is often supplemented by a channel termed the *bye-wash*, which is used to divert the streams supplying the reservoir, so as to prevent fouling of the store-water. The flood-water carried off in this way flows into the natural water-course.

784.—*Describe the mode of action and the uses of a Waste-Weir.*

The waste-weir is an appendage essential to the safety of every reservoir. It is a weir at such a level, and of such a length as to be capable of discharging from the reservoir the greatest flood-discharge of the streams which supply it, so as not to allow the water-level to rise to a dangerous height. The water discharged over the weir is to be received into a channel, open or covered, as the situation may require, and conducted into the natural water-course below the reservoir embankment. The weir is to be built of ashlar or squared hammer-dressed masonry; the bottom of the waste channel, directly in front of it, is best protected by a series of rough stone steps, which break the fall of the water. Instead of a waste-weir, a waste-pit has, in some cases, been used, that is to say, a tower rising through, or near the embankment to the top water-level; the waste water falls into this tower and is carried away by a culvert from its bottom; but the efficiency and safety of this contrivance are very questionable, for it seldom can have a sufficient extent of overfall at the top. (See next No.)

5.—*What is the overflow or waste-weir?*

The overflow or waste-weir is an appendage essential to the safety of every reservoir. It is a weir at such a level and of such a length as to be capable of discharging from the reservoir the greatest flood discharge of the streams which flow into it. Knowing this discharge, and allowing a maximum depth of say 6 inches over the weir, the length of the latter may be easily calculated The weir should be built of ashlar or square hammer-dressed masonry. Instead of a weir, what is known as a waste pit is in some cases used; this is a tower rising through or near the embankment to the top water-level, into which the waste water falls, and is carried away by a culvert at the bottom. But as such a tower can seldom have a sufficient extent of overfall, the safety it affords is questionable. The water that flows over the waste-weir is conducted away to the natural water-course by a bye-wash or channel. This bye-wash may be much narrower than the weir, as the water may flow through it with an increased depth. In all cases the bye-wash should be cut round the end of the embankment, and not brought over the embankment itself. Sometimes it is cut to take the flood waters without allowing them to pass into the reservoir, and this plan is preferable for several reasons. Usually the waste weir is segmental in form, and a fall of 1 or 2 feet is allowed on the down-stream side. To prevent too great a velocity in the channel by which the water is conveyed to the natural course the channel should be carried along level for some distance from the reservoir. Some engineers break the floor occasionally by steps. When steps are used, the fall should not be more than 9 inches; and the tread of the step should be equal to at least twice the fall. Near the reservoir, a layer of concrete should be placed under the bottom of the bye-wash.

786.—*What is the object of a Weir?*

It is partly to make a small store reservoir, but principally to prolong a high top water-level from its natural situation at a place some distance up the stream to a place where water is to be diverted from the stream to drive machinery, or for some other purpose.

The weir is constructed across the stream so as to dam up a nearly still pond of water behind it, from which the whole flow of the stream escapes through a notch, or other suitable sharp-pointed orifice in a vertical plate or board, the elevation of still or nearly still water being observed on a vertical scale in the pond, when zero point is on a level with the bottom of the notch, or with the centre of a round or rectangular orifice.

787.—*What is a Moveable Weir?*

A moveable weir is generally a water-tight planted timber gate, or fall door turning on a horizontal hinge at its bottom, so as to be flat in a recess in the bottom weir when open. It must open down-stream and may be supported at any degree of opening by an arrangement on the down-stream side.

788.—*Name an essential requirement of a Weir.*

A weir always requires waste sluices or flood gates.

789.—*What is a Sluice?*

It is a sliding valve of wood or iron moving in vertical guides or grooves inside a rectangular passage or tube of masonry. It is generally moved by a screw or a rack and pinion joint.

790—*How are the Sluices brought into use?*

They may either be under the control of a man in charge of the reservoir, or they may be self-acting. Water sluices may be opened to assist the waste weir in discharging an excessive supply of water.

791.—*State briefly the precautions to be observed in the Construction of large Reservoirs.*

Large reservoirs are made water-tight by a core of clay puddle; the inner slope is protected by a pitching of dressed stones, the outer by a covering of grass sods; the summit of the embankment should be 3 to 10 feet higher than the water-level; the top is covered with broken stones; no trees or shrubs must grow on it; and care must be taken to prevent the possibility of rats burrowing into it; an overflow weir is provided to permit of discharge of flood-water from the drainage area, and is supplemented by a bye-wash, which diverts the foul flood-water of the streams supplying the reservoir; there is a cleansing-pipe at the lowest level; the discharge-pipe bends upwards, and is perforated with holes at different heights, and has guards to prevent entrance of stones, wood, etc. Certain plants, as *protococcus* and *chara*, give off oxygen, and may be allowed in reservoirs; but duckweed (*lemna* and *pistia*), and all dead vegetable matter, should be removed.

792.—*What are the objects served by .*

Reservoirs generally have for their object either the detention of flood-water that might otherwise cause damage, as in works of river improvements, or the utilisation of it in canals, of navigation, irrigation, or driving machinery, or for town supply. For the first purpose they must, toeffect their purpose, be very extensive as this, and even if there were no other considerations at least half a day's demand should be provided. Under the intermittent system the required capacity of the service reservoir will depend to a certain extent, upon how the system is worked.]

798—*Give an example as to the method of calculating the required size of a reservoir.*

Suppose that a population of 100,000 is to be supplied with 25 gallons per head per day, which is equal to a total of 2,500,000 gallons per day, and suppose, further, that the supply is to be taken from a catchment area, over which the mean annual rainfall is, say, 42 inches. Deducting one-sixth, or 7 inches, there will be 35 inches for the fall during three consecutive dry years, which we will make the basis of the calculation. The square root of 35 is 6 (nearly), and 1,000 divided by 6 is equal to 166, say 170 days' storage. In addition to the above two and half million gallons per day, there will be, suppose, 1,000,000 gallons per day, to be given as compensation to streams, and 160,000 gallons per day to be lost by the evaporation, of say, one-tenth of an inch per day from the surface of the reservoir of say 70 acres. The total demand will therefore be 3,660,000 gallons per day. The dry weather flow into the reservoir we will assume as a little less than half a cubic foot per second from each 1,000 acres taken over an area of, say, 2,500 acres. This will give 600,000 gallons per day, which deducted from the total demand, will leave 3,060,000 gallons per day. This quantity multiplied by 170 for the number of days' storage, will be 520,000,000 gallons, the required available capacity of the reservoir.

The storage capacity may be taken as a certain number of days of the excess of the demand over the dry weather flow, that is to say, the average of the quantity which may be expected to pass into the reservoir during the drought. This may be ascertained from a series of comparisons of actual gauging with the rainfall during the same period. Should there be rainfall records of more severe droughts, the corresponding minimum flow of the streams will be still less in proportion to the fall of rain; for the loss by evaporation will be proportionately greater as the ground surface is hotter and more parched. In districts that are generally selected as catchment areas for town supplies, a dry weather flow of from one-quarter to three-quarters of a cubic foot per second (that is from 135,000 to about 400,000 gallons per day) per thousand acres, may be expected. Great caution however must be exercised in making allowances under this head, and a careful study of judiciously arranged gaugings should invariably be made.

After having ascertained the greatest excess of the demand above the supply, it remains to be decided how many days' storage will be required. As before stated, the number of days' storage required will be greater as the mean annual rainfall is less. Thus in many parts of the west of England when the rainfall is greatest, 100 or 120 days' supply will be sufficient, while 240 or 250 days' supply will be required in the East, when the total rainfall is less and the droughts are longer. It would appear that the storage capacity should vary inversely as the square root of the rainfall taken for three consecutive dry years, and moreover that if the constant number 1000 be divided by this root, a fair idea of the number of days' storage required will be obtained. The discovery of this law is due to Mr. Hawksley and was arrived at only after many years of extensive observation.

799.—*How may the water collected in a storage reservoir be calculated?*

By ascertaining the area of the collecting basin, the average rainfall, and the average amount of percolation, evaporation and flow of rainfall off the surface.

800.—*In calculating the capacity of a reservoir what allowance must be made?*

A certain space must be left below the lowest working level that is not available for storage. The use of this bottom (as it is called) is to collect the sediment from the water. The extent of this bottom varies under different circumstances. But it is well to allow a depth that at the lowest working level no portion of the bed at a distance of 3 feet from the water's edge shall be less than 6 inches from the surface.

801.—*In calculating the capacity of a reservoir, what must always be ascertained?*

The space left below the lowest working level that is not available for storage.

802.—*What is the use of this space?*

The use of this space, or bottom, as it is termed, is to collect the sediment from the water. No rule for the volume of the bottom can be deduced from existing examples, for here again we find a total want of uniformity. Some engineers give a depth equal to one-sixth of the total depth of the water at the deepest part of the reservoir; but it is difficult to discover on what basis such a calculation rests. The object being to allow a depth of still-water above the bottom for the purpose of preventing sediment from being drawn off, this end would probably be best obtained by allowing such a depth that at the lowest working level no portion of the bed at a distance of 3 feet from the water's edge shall be less than 6 inches from the surface.

803.—*What is meant by the available capacity of a reservoir?*

The *available* capacity, or storage-room of a reservoir, is the volume contained between the highest *total* capacity by the volume of the space below the lowest working water-level which space is left as a place for the collection of sediment, and is either kept always full, or only emptied when it is absolutely necessary to do so for purposes of cleansing and repair. It is impossible to lay down a universal rule as to how much the space so left, or "bottom," is, but in some good examples of artificial reservoirs, it occupies about one-sixth of the greatest depth of water at the deepest part of the reservoir. The absolute storage-room required in a reservoir is regulated by two circumstances,—the demand for water, and the extent to which the supply fluctuates.

The best rule for estimating the *available* capacity required in a store-reservoir, would probably be one founded upon taking into account the supply as well as the demand.

In order that a reservoir of the capacity prescribed by the preceding rule may be efficient, it is essential that the least available annual rainfall of the gathering-ground should be sufficient to supply a year's water-supply.

[The foregoing principles as to capacity have reference to those cases in which the water is to be used to supply a demand for water. When the sole object of the reservoir is to prevent floods in the lower parts of the stream, it ought to be able to contain the ascertained greatest total excess of the available rainfall during a season of flood above the greatest discharging capacity of the stream (consistent with freedom from damage to the country).]

804.—*Define briefly what is meant by the available in a reservoir.*

It is the volume between the surface and the lowest working level.

805.—*When the capacity of the reservoir has been determined, upon what will its dimensions depend?*

Mainly on the character of the site. Depth is essential to the purity of the water, for in shallow water the growth of plants is very rapid. Moreover, as evaporation depends upon the extent of surface exposed, the loss from this cause will be less as the depth is increased. For these reasons, a reservoir should always possess considerable depth.

806.—*What should be the dimensions of storage-room?*

The storage-room should be large enough to contain a four or six months' supply; and the site which can supply the requisite storage-room with the least embankment, the least amount of puddle and the least area laid under water is to be preferred.

807.—*What points is it necessary to be acquainted with to determine the amount of water to be stored when dependent on rainfall?*

(1) Amount used, and (2) ease of replenishing. This latter depends upon the rainfall and upon the area of catchment.

808.—*By what rules may we calculate size of reservoir ?*

Number of gallons required daily for whole population ÷ by 6·23 to bring to cubic feet and × by number of days the supply is to last = size of reservoir in cubic feet.

809.—*What quantity of water should an impounding reservoir contain ?*

About 120 days' supply in rainy districts, and 200 days' supply in the less rainy districts of England.

810.—*What supply should service reservoirs contain ?*

About 3 days' supply. With a catchment area large in proportion to population, and with a fairly distributed rainfall, the necessary storage space will be less than in a district where there are long droughts to be provided for, and where, the catchment area being small, it is essential that loss by escape of water during heavy floods should be minimized by providing large reservoirs.

In dry seasons the reservoirs will not be full. In flood-time the excess of water flows over a weir at a fixed height into a 'bye wash' or side channel, and thence into the main stream.

The amount of storage required for the water-supply of a town necessarily varies, not only with the numbers of the community to be supplied, but also according to their habits, and the industrial occupations carried on; and in manufacturing towns the amount of water required for industrial purposes may exceed that required for domestic use. Whatever be the required daily supply, the storage capacity of the reservoirs in rainy districts should equal 150 days' dry weather supply (Pole); and in dry districts 200 days' supply.

Dr. Pole (*Water Supply*, p. 21,) has given some simple and useful formulæ for calculating the collecting area requisite, where the rainfall is known, and the loss from evaporation fairly established.

If R=the mean rainfall in a given year, in inches,
E=the estimated loss by evaporation, etc., in inches,
A=the area of gathering ground in acres,
then gallons of water per day$=62A\ (R-E)$,
and cubic feet of water per year$=3630\ A\ (R-E)$.

811.—*Upon what does the size of an impounding reservoir depend ?*

Upon the amount and fluctuation of the supply.

812.—*What regulates the size of the storage reservoir ?*

It depends upon the amount and fluctuation of the supply; usually 120 days' supply is the least of any used, but 140 days' supply is however nearly always sufficient.

813.—*What should be the storage in the dryer districts ?*

At least 200 days' supply.

814.—*What is Hawksley's formula for calculating the capacity of the storage reservoir?*

Hawksley's formula for storage is $D=\frac{1000}{}$

D being number of days' supply to be stored, F mean annual rainfall (five-sixths of average). Storage capacity may vary from 25,000 to 50,000 cubic feet per acre of catchment area.

815.—*Explain Hawksley's formula and give an example as to how the calculation is worked out.*

Mr. Hawksley's formula for calculating the number of days' storage requisite is to divide 1000 by the square root of the annual rainfall in inches. Thus, with a rainfall of 36 inches, the day's storage required is $\frac{1000}{\sqrt{36}}=\frac{1000}{6}=167$ days; and with a rainfall of 64 inches is $\frac{1000}{\sqrt{64}}=\frac{1000}{8}=125$ days.

816.—*How may we calculate the required size of a reservoir?*

The number of gallons required daily for the population divided by 6¼ (which calculation reduces it to cubic feet of water), multiplied by the number of days' supply required: the result is the size of the reservoir in cubic feet.

817.—*What should be the storage-room in relation to the catchment area?*

From 25,000 to 50,000 cubic feet per acre of catchment area.

818.—*Upon what basis is the capacity of a storage reservoir calculated?*

In constructing reservoirs the storage capacity is estimated from the number of dry consecutive days, likely to be experienced in any given locality. [In England this is seldom more than a month.]

819.—*Discuss the questions related to the matter of storage.*

The amount of storage required will depend on the following circumstances, *viz.*, the amount used and the ease of replenishing. It is, of course, easy to calculate the space required when these conditions are known, in this way:—the number of gallons required for the daily whole population must be divided by 6·23 to bring into cubic feet and multiplied by the number of days which the storage must last; the product is the necessary size of the reservoir in cubic feet. Hawksley's formula for storage is as follows:—$\frac{1000}{\sqrt{F}}$, where F equals the annual rainfall in inches; the resulting number is the number of days' storage required. Thus, with a rainfall of 25 inches, we have $\frac{1000}{\sqrt{25}}=\frac{1000}{5}=200$ days.

[Whatever be the size of the reservoir, it should be kept carefully clean, and no possible source of contamination should be permitted.]

Many waters, particularly rain-water, must be filtered through sand before they pass into small cisterns, and the filter should be cleaned every three or four months. A double filter can be made by having a second chamber.

820.—*Is a certain amount of vegetable life good for store reservoirs?*

Yes; the presence of moderate quantity of living plants, exerts a decidedly purifying influence, while the destruction of fish has been followed by an excessive multiplication of the small crustacean animals on which the fish had lived, thereby rendering water nauseous and impure. The remedy was found in re-stocking the reservoir with fresh fish (RANKINE).

821.—*What other precautions are to be taken?*

That the storage reservoir be well protected from contamination by cattle, and by excreta of human beings. They should be kept free from weeds, some of which may communicate an unpleasant taste to the water; and all dead and decaying vegetable matter is more or less injurious. When in the neighbourhood of towns and factories, the reservoirs should be covered, so as far as possible to exclude contamination by solid particles floating in the atmosphere.

All reservoirs require to be frequently cleaned; they should be covered in, and ventilated; in form, deep rather than extended, so as to lessen evaporation and secure coolness. If too large to be covered in, a smaller covered one with a filter between should be provided, containing three days' supply.

822.—*By what formula may we calculate the time employed in filling and emptying a reservoir when the supply and consumption are going on simultaneously?*

Q = Supply of water to reservoir in cubic feet per minute.
q = Consumption of water from reservoir in cubic feet per minute
C = Contents of reservoir in cubic feet.
T = Time required for filling reservoir in minutes.
t = Time required for emptying reservoir in minutes.

$$T = \frac{c}{Q-q} \qquad t = \frac{c}{q-Q}.$$

823.—*How does the water pass from the reservoir?*

Through aqueducts by an outlet-pipe which is bent upwards at its commencement, so as to take only the purest water free alike from sediment and floating matter.

824.—*What would be the storage-room required for the water collected in an area 200 sq. ft. with a rainfall of 20"?*

Reduce the 200 sq. feet to sq. inches and multiply by 20, which gives the number of cubic inches divided by 1728, gives the actual amount of water in cubic feet to be stored.

825.—*When a large and crowded area has to be supplied what precautions are to be taken?*

The additional expense in piping which would be thus entailed is sometimes so great that distributing basins or town-reservoirs are constructed to supply certain districts. To meet all emergencies, they are made large enough to contain at least a day's supply, and they must also have a site of sufficient elevation to ensure distribution by hydrostatic pressure. Every such reservoir should be roofed in and ventilated, to protect the water from frost and heat, and from becoming tainted with aërial impurities.

826.—*Are spare reservoirs necessary in towns?*

They frequently are, particularly when the requirements vary at different periods of the day and the greatest hourly demand is double that of the average demand.* [These reservoirs should be of a capacity sufficient to hold one day's supply, and they should be both covered and ventilated.]

827.—*What are the chief points attended to in the construction of supply reservoirs or distributing basins?*

To meet all emergencies, they are made large enough to contain at least a day's supply, and they must also have a site of sufficient elevation to ensure distribution by hydrostatic pressure. Every such reservoir should be roofed in and ventilated, to protect the water from frost and heat, and from becoming tainted with aërial impurities

828.—*What daily supply and volume in the storage reservoir would you consider necessary for a population of 90,000?*

At least 20 gallons each, or 1,800,000 gallons storage should be provided for 6 weeks' supply.

$$90{,}000+20+32 = 75{,}600{,}000 \text{ gallons}$$

for which storage room is required and this $\div 6\frac{1}{4}$ = cubic capacity necessary in ft. with a reservoir 500 feet. sq. depth, would be $\frac{265{,}000}{5} = \frac{530}{5}$ = 106 per day.

829.—*What arrangements are necessary for removing the sediment which collects in the bottom of the reservoir?*

In order to remove the sediment which collects in the bottom of the reservoir, there is always a cleansing pipe, as well as a discharge pipe, the former being on a level with the lowest point in the reservoir and discharging with the natural water course below the embankment. Both are carried through a culvert in the embankment, which is built of stone or brick, and founded on the solid rock. The aqueduct or discharge pipe bends upwards in the reservoir, and has a series of inlets, the lowest at the lowest working level, and the whole of them guarded against the entrance of small stones, pieces of wood, or other bodies, which would interfere with the action of the valves. The sluices which are required for both pipes are situated in the reservoir, and are worked from the sluice-tower.

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* RANKINE'S *Civil Engineering*.

As already stated, storage or impounding reservoirs are necessarily settling reservoirs; indeed all reservoirs are so to a greater or less extent. The area and capacity of which storage reservoirs as such have to be made is generally in excess of that required for efficient settlement, so that seldom, if ever, will an addition have to be made to the capacity of a storage reservoir, in order especially to allow of the complete subsidences of suspended matter. For even when there is an exceptionally small quantity of water in the reservoir, say only a week's supply, it will in most cases be at rest to all intents and purposes; in other words, the velocity of the current towards the outlet will be far lower than will be likely to interfere with the settling process. The case is different where large storage capacity is not required, and where reservoirs have to be provided expressly for the purpose of purifying water by subsidence, as, for instance, where the supply is derived from a turbid river whose flow is greatly in excess of the requirements of the works. Here the object will, of course, be to provide for the settlement of the mechanical impurities with the least possible expense.

830.—*If house cisterns are indispensable, what precautions should be taken in regard to their construction?*

Where house cisterns are indispensable, they are best constructed of well-cemented slate slabs, which should be thoroughly enamelled inside. A wrought-iron cistern coated with some bituminous compound has been recommended by many. The ordinary iron tank reservoir similarly coated is very useful, although from the absence of fresh air, if it is not thoroughly looked after, the water in it rapily deteriorates. A cistern of thoroughly glazed and cemented bricks is also a convenient form of construction for house cisterns. Lead cisterns should never be used in a house. Galvanised iron is also objectionable. Another important point is, that the service pipes which convey the water from the mains and sub-mains to the housetops or cisterns, should never be composed of lead or galvanised iron. A safe pipe is a leaden one lined with block tin.

Wooden cisterns should likewise be avoided, as the wood is ap decay, to favour the putrefaction of, and impart organic impu to, the water.

831.—*What materials are frequently employed in the construc of cisterns?*

Lead, slate, galvanised iron and zinc. Stone, glass, brick li with Portland cement, glazed earthenware and lime are likew used.

832.—*What are the objections against iron, zinc and lead cister*

Iron cisterns rust and discolour the water and give it a ch beate taste; zinc is rapidly dissolved by water and produ poisonous effects; lead is dissolved at first when the cistern is n but rapidly becomes coated with carbonate or sulphate of l when the water is hard, or with a carbonate and oxide when water is soft. Soft waters act upon lead, dissolve it to a danger extent and thus bring about lead-poisoning.

833.—*Why is zinc so commonly used?*

On account of its cheapness.

834.—*What is the best material for house cisterns?*

Slate, well set in hydraulic cement.

835.—*What special points are to be attended to in regard to cisterns?*

They should be properly covered and protected from heat and frost and foreign bodies. They should be periodically cleaned and inspected. They should be well ventilated and placed in a well lighted locality. They should not be in proximity to water-closets or sleeping apartments. They should have no communication with the water-closet, the water-supply should if possible be absolutely distinct. The waste pipe should not communicate with the drain or sewers directly. All cistern-water should be thoroughly filtered after leaving the cistern if the water is to be drunk, or a small filter may be placed in the cistern, so that the tap connected with the latter delivers filtered water. Cisterns are always a danger to the purity of water, and if possible there should be no cisterns in the house beyond that for the kitchen boiler and water-closet. Cisterns frequently leak, therefore it is necessary to have them placed in such a position that should they leak no harm will accrue.

836.—*Is zinc as bad as lead for cisterns?*

It is not; but as it is also poisonous, although not to the same extent as lead, it should be avoided for cisterns.

837.—*If a lead cistern must be used what precaution must be taken to commence with?*

That the whole of the water of the cistern should be allowed to run out as in all probability it will have dissolved out some of the lead.

838.—*What effect has hard-water on lead cisterns?*

It causes a deposit upon the inner surface of the cistern consisting usually of carbonate or sulphate of lead. These deposits form a lining which protect the surface of the metal from further action. It is for this reason that the inside of a leaden cistern should never be scraped when the cistern is being cleaned out.

839.—*What is the effect of washing and scouring out leaden cisterns?*

If there is a deposit of insoluble lead salts, this protective coating over the lead is removed and exposes the fresh bright lead surface to the action of the fresh water, with the certainty that some would be absorbed before another protective coating was deposited. Lead cisterns therefore should not be washed and scraped as other cisterns usually are.

840.—*What is the objection to stone cisterns?*

They are too heavy except in basements.

841.—*What form of cistern is recommended by Professor* CORFIELD?

Galvanised iron; that is, iron which is coated with a thin layer of zinc.

842.—*How may the rusting of iron cisterns be prevented?*

By giving them a coating of boiled linseed-oil before they leave the foundry, or coating them with a bituminous material.

843.—*What is the objection to slate cisterns?*

They are apt to leak; the points of leakages are not uncommonly smeared with red lead, which is attacked by the water, and thus lead poisoning results. If the slate is set in good cement (not mortar, as this makes the water hard), it is perhaps the best of all materials for a cistern.

844.—*How may lead cisterns be protected?*

By giving them an inside coating of tar, pitch, or other preservative material, or by a layer of block tin (Haines' patent).

845.—*What is the first essential requirement of house cisterns?*

That they should not be constructed of a material that will impart any injurious quality to the water. [Galvanised iron [and slate both answer the purpose well; the latter, however, although the best in other respects, is heavy and it is difficult to avoid leakage through the joints; these should be carefully made with cement. The risk of metallic contamination in the case of the former has often been demonstrated.]

846.—*What is the next most important point in connection with house cisterns?*

They should be easily accessible, and, while the sun's rays ought to be excluded, the place where they are fixed must not be dark. This requirement is essential so as to afford every facility for inspecting and cleansing. It is not unusual to find cisterns placed under floors by reason of the foul condition of the water, a search is made, and the cause, in the shape of dead and decomposing rats, is discovered. They should be protected from frost. Cisterns, where, as, under the intermittent system, they are necessary, should likewise be secured from frost and sun, as well as from all chance of the entrance of dirt, dust, etc. Two situations very commonly selected by builders are equally to be condemned—one is the immediate neighbourhood of the water-closet, chosen with the object of saving a few feet of pipe; and the other, for security from frost, is beneath the flooring of a landing or bath-room, where dust, slops, and the like find ready entrance.

847.—*What other points are necessary in connection with house cisterns?*

They ought to be covered and ventilated, otherwise dirt of all description will enter.

The overflow-pipe ought to be carried to the outside where it should either be cut short or discharge on to an open gully. It is a very common practice to connect it direct with the soil pipe or drains, in which case it simply acts as a ventilator, and foul gases are conducted direct to the drinking-water. In some instances in which this is done a siphon-trap is introduced, but as the overflow pipe is only in use when the ball-tap, which regulates the supply of water, is out of order, this trap, owing to evaporation must stand empty, and, therefore, be absolutely useless.

The supply-pipe for the water-closet must not pass direct from the cistern, but a smaller cistern (water-waste preventer) ought to be interposed.

848.—*What is the best means of storing water?*

In all such cases the best mode of storing water is in underground tanks constructed of sound masonry with vaulted roofs and lined with hyradulic cement. It is thus secured from contamination and from the influence of changes in the external temperature to which cisterns above ground are liable. Thus Captain Galton observed the temperature of a well to vary only between and 51·5° during the year, that of the water in the mains between 39·7° and 64·8°, and that of the cistern between 33·6° and 71·5°, showing an annual range of 1° in the well water, 25° in the mains, and 38° in the cisterns.

To indicate briefly the conditions under which water may be safely stored in houses the following rules should be observed :—

(*a*) The cistern should be of stone-ware, slate, or galvanised iron;

(*b*) It should be placed in a light and well-ventilated position, and should be properly covered;

(*c*) It must not be used to flush water-closets, but may supply the "intercepting" or waste-preventing cisterns, which should be used for this purpose;

(*d*) The overflow pipe must be carried out into the open air to terminate as a warning pipe; it may end over the open head of a rain-water pipe if the cistern is in an upper storey, or over a trapped siphon gulley when the cistern is near the ground;

(*e*) The cistern should be cleaned out at regular intervals;

(*f*) The inlet to every cistern ought to have a cock with a float to rise and stop the supply when the cistern is full.

849.—*What other precaution is necessary?*

Every cistern should have a well-fitting lid, always kept closed; otherwise, not only dust gets in the water and noxious gases, but also decomposing vegetable matters, and even dead cats, birds, etc.

850.—*With regard to house storage of water what opinion did the Rivers Pollution Commissioners express in their Sixth Report?*

"All storage of drinking-water in houses is attended with the risk of pollution. Good water is spoiled, and bad water rendered worse, by the intermittent supply (house storage being inseparable from this form of supply)."

851.—*How may the connection of the overflow pipe with the house drainage system pollute the cistern water?*

Suppose that the overflow pipe has a S bend on it before its junction with the drain, but as the water in a trap quickly evaporates when not renewed—and the water in this trap can only be renewed if the ball-cock of the cistern leaks—little obstacle is presented to the passage of foul, and possibly infected, sewer air from drain, soil-pipe, or D trap, up the overflow pipe, where it escapes over the water of the cistern. This direct connection of the overflow pipe with the drainage system is said to be one of the chief causes of the spread of typhoid fever in towns.

852.—*What danger is likely to arise if the house cistern communicates with the water-closets, and how may such risk be avoided?*

The danger of sewer gas rising through the pipe. There should be a special small cistern for the use of the closet. What are termed water-waste preventers are now commonly used, fed either by a cistern or by constant supply. They are boxes which are emptied into the pan, by a valve and are then re-filled. There are many kinds, but perhaps the best are those that work by siphon action, brought into play by pulling a wire. The amount of water should not be less than two gallons, and the fall should not be less than 3 or 4 feet, so as to insure thorough scouring of the soil-pipe.

853.—*What other precaution is necessary with regard to stored water?*

Any water collected in the house for intermittent use during the day should be carefully protected from all possible sources of pollution, and the receptacle for the water should be periodically cleaned.

854.—*State briefly the conditions under which a cistern is least liable to yield impure water?*

A cistern, if any is needed, should be placed at the top of the house, and fed by a supply-pipe controlled by a ball-cock. It must be large enough to contain at least a day's supply, and must not directly supply the water-closet. It may be made of lead, lined with pitch or other protective coating, or of galvanised or Barff iron, or of slate slabs set in cement. It should be closely covered, but ventilated, and provided with an overflow discharging into the open air away from any source of effluvia. Frequent inspection and cleaning are necessary.

855.—*What prevents further flow of water when the house cistern is full?*

A ball-tap prevents any further flow of water; and if this does not act properly, an overflow-pipe carries off the excess of water.

856.—*Compare the merits of the different materials used in the construction of house cistern?*

For the private storage of the inhabitants—slate, lead, iron, and zinc cisterns are most used, on account of the cheapness of the material. Lead is open to the objection of the poisonous nature of the soluble compounds sometimes formed by the action of the water on the metal. Slate cisterns are difficult to keep water-tight; and if iron is used, it should be coated with the patent material used for water-mains. All cisterns should be kept covered to prevent contamination, but free ventilation should be provided. They should also be placed so as not to damage the house or render it damp in case of leakage, and also be easy of access for inspection, cleaning, etc. Care must be taken that the waste does not communicate with the drains or closet-trap, but that it opens into the open air. A practice formerly common in London was to carry the waste-pipe into the closet-trap. All cisterns should be inspected and cleaned periodically.

857.—*Name another source of pollution from connection with drains.*

Drinking-water in cisterns becomes liable to a very dangerous pollution by the very general practice of connecting the "standing waste" or overflow-pipe of a cistern with a drain or soil-pipe of the house, or with the D trap under a water-closet.

858.—*What are the chief objections to cisterns?*

(1) The danger of pollution of the water by sewer air, dust, soot, and accidental contaminations such as dead mice, birds, or cockroaches, and (2) the risk of solution of the material of which the cistern is composed.

859.—*Where the overflow-pipe joins the soil-pipe below the siphon of the water-closet, what may occur?*

Sewer gas may mount directly into the cistern and be absorbed by the water; where it is joined to the trap of the siphon on the side nearest the water-closet pan, only the offensive gases from the water-closet can, as a rule, mount into the cistern.

860.—*Should the water-closet be supplied from the same cistern as supplies drinking-water?*

It should not, for the pipe leading down to the closet often carries closet air to the cistern. A small cistern or service-box should be provided for each closet.

861.—*What special points must be attended to in the cleaning out of cisterns?*

The cistern must be frequently cleaned out, at least once every two or three months, all chips of mortar, etc., being very carefully removed, as they speedily corrode the lead or iron. It should always be cleaned out when, for example, the family returns from summer holidays, and before drawing any water for cooking, drinking, etc., from it. It should be cleaned out with a soft hearth brush, lightly rubbed over it and with plenty of water; the sides must on no account be scrubbed with a hard brush, or with sand or anything rough, as this would remove the protective coating. After heavy rains, by the melting of snow and the breaking up of ice, rivers are more than usually turbid, and the filtration of the water is less perfect. In the hot months of the summer again, though the water supplied may be at its best, the suspended matters which tend to accumulate in a cistern undergo rapid decomposition, and for this reason the water should be allowed to run off or the cistern be emptied for garden or other purposes.

862.—*Cisterns are occasionally used to supply water-closets which have regulator valves on the supply-pipes. Is this advisable?*

Although there is but little danger of foul air finding its way into the drinking-water of the cistern, by this arrangement, as the supply-pipe is always full of water unless the cistern is empty, still it is better to break the connection altogether between drinking-water cisterns and water-closets.

863.—*What are the chief pionts to be attended to in regard to the overflow-pipe of a cistern?*

It should never open into a sewer or water-closet pipe, because, even though properly trapped, the water seal may disappear by evaporation and the gases pass up and be absorbed by the water. It must have no communication with any other overflow or waste soil-pipe or drain. It should pass through an external wall and discharge by an open end, some little way above the ground, over a trapped grating, it should not however, be near an intercepting drain, trap or its grating, because if the trap evaporated, then gases are apt to be drawn up the pipe, by the warmth of the house, to the cistern. A very safe and good plan is to let the overflow-pipe open into the roof gutters. The end of the overflow-pipe should be easily seen so as to detect any unnecessary waste. The overflow-pipe should be used only as a warming-pipe, and open on the outer wall so that it can be readily seen. In this manner it apprises the occupants of the fact that something is wrong, as the cistern will not overflow unless there be something wrong with the valve of the inlet-pipe. It may also open into the bath or over a sink

It should never be connected with the drainage system, but should be made to discharge its contents over a properly trapped gully. But in dry weather there is risk that the gully may become unsealed owing to the evaporation of water in the trap, and therefore when it is possible, the waste-pipe of a sink, lavatory or bath which is frequently in use, should be made to discharge into the same trap, and thus ensure that it shall always be charged with water.

In short an overflow pipe from a cistern should never lead directly into a sewer, but should end above ground over a trapped and ventilated grating. If this were always attended to, no sewer gases could find their way to the cistern through this channel.

864.—*What else is necessary as regards the trap connected with the waste-pipe?*

That from the trap the waste should be carried as rapidly as possible through the wall and then made to descend to the gully. The ventilation of the trap which is needed to prevent siphonage when the waste-pipe is long, or when two or more waste-pipes are connected, is effected by the insertion of an air-pipe into the top of the trap beyond the seal, the other end being carried through an external wall into the open air.

865.—*What precautions should be observed as regards the waste-pipe of cisterns?*

As a rule, a waste-pipe should not only be as short as possible, but it should also be easily accessible at the outer end, so as to allow of its being periodically cleansed by means of a brush being passed into it The trap in the waste-pipe should be of the simple S form, and furnished with a brass screw-plug, in order to afford access to it for purposes of cleansing it and removing obstacles such as pieces of flannel, hair, stumps of lucifer matches, etc, which frequently get into the pipe. The trap should always be formed in the course of the pipe itself, the continuity of the circular bore being carefully preserved. Excellent cast lead pipe-traps of various diameters, with suitable screw inspection-holes, are manufactured expressly for the purposes above referred to.

866.—*What are the best form of cisterns?*

Siphon waste-preventing cisterns are to be especially commended.

867.—*Where should the overflow-pipe from a cistern end?*

It should never lead directly into a soil-pipe, sewer, or drain, but should end above ground over a trapped and ventilated grating. If this were always attended to, no sewer gases could find their way to the cistern through this channel.

868.—*What should be the diameter of the waste-pipe?*

If the waste-pipe has a diameter of 1½ inch, this will be sufficient even for baths, and if two or more be joined, they may discharge into a somewhat larger pipe . a good arrangement is then to carry a ventilating pipe from the upper end of the common pipe, to some convenient position above the level of the windows.

869—*What precautions should be observed as regards the service-pipes from the cistern?*

The service-pipes from the cistern should be so arranged that by means of a stop-cock immediately under the cistern, or as near thereto as possible, the water may be shut off from the pipes, and they may be emptied whenever necessary, either for repairs or on the approach of frost. This is a most useful arrangement, and one that ought not in any case to be omitted. It is necessary to observe, moreover, that in fixing the pipes, every pipe should be so arranged as to allow it to empty itself completely when the supply has been shut off at the cistern by means of the stop-cock above referred to, and when the tap at the outlet has been opened. Water-pipes, as a rule, should not be fixed in positions where they are specially liable to draughts of cold air; hence they should not be placed immediately beneath a window, because in cold weather the current of cold air passing downwards from the window, even though the window be closed, is very liable, under certain conditions, to cause the water in the pipes to freeze.

Pipes for conveying water from the main supply-pipes in the roads are, in London, almost invariably of lead. The bye-laws of the metropolitan water companies compel the use of lead pipes when fixed under-ground.

870.—*What is the best method of treating the waste-pipes of cisterns ?*

To carry them through the external walls and leave them open in that situation, so that, on the one hand, no unwholesome emanations can enter the cistern, and, on the other, the waste of water resulting from a faulty ball valve is at once seen, and can be remedied. But the wastes of sinks, lavatories, and baths must be differently dealt with. Unless the sink is of the kind known as a slop-sink, and used for disposal of urine, a circumstance that requires it to be treated as a water-closet, all wastes should be made to discharge over trapped gullies in the open air. Such *disconnection* renders it impossible for the air from the drain to enter the house.

a part of the water-supply system in which great waste occurs ?

In water-closets. Many engineers are of opinion that the great waste which is sometimes complained of, is owing to water-closets.

872.—*What are waste-water preventers ?*

They are rectangular boxes holding a definite amount of water, and usually so arranged that they may be emptied on the siphon principle. Each time the closet is used the quantity of water in the "preventer" is discharged into the pan. This contrivance prevents the water being turned on and permitted to flow indefinitely.

873.—*What is the quantity of water legally prescribed to flush a W. C. ?*

Two gallons.

874.—*Is this sufficient ?*

Only if the pan is of perfect construction and the pipes are well laid and not too remote from the surface sewer.

875.—*What means are adopted to prevent water-closet waste in the water-closets ?*

In towns with a constant supply, small cisterns, termed water-waste preventers, have been introduced, to permit only a certain amount of water to flow into the pan each time the closet is used.

876.—*What is the great objection to a large number of these waste-water preventers ?*

They are generally too small, so that neither the pan nor the soil-pipe is thoroughly flushed, and there is the consequent risk of filth accumulation.

877.—*Is there any danger in supplying the water-closet with water from the general cistern of the house?*

There is considerable danger,—unless the closet have adapted to it a "waste-water preventer," or the pipe between the cistern and the water-closet is kept constantly full of water—the supply valve should be attached to the water-closet and to the pipe. In cases where the supply valve is at the cistern end it is impossible to keep the water pure, as the pipe between the cistern and the basin, in the intervals of use, is full of gas drawn up from the basin and closet, and the next time the supply valve is opened, the gas bubbles up through the cistern water, much of it is, of course, absorbed. The water-closet should always have a separate cistern.

The supply-pipe is always furnished with a stop-cock or valve, raised by a floating ball, to cut off the inflow when the cistern is nearly full. Of these there are a great many patterns to be found in catalogues, but ball valves have nearly superseded ball cocks, being less liable to get out of order. Among the best is that of Tylor and Sons, in which the jerking caused by the agitation of the water as it enters, which is often very great, is borne by the lever only. Underhay's equilibrium, and Tylor's high pressure ball valve, both working horizontally, permit of a full stream passing until the cistern is all but full, and the latter is specially suited for sustaining a high-pressure. A very cheap and ingenious form is the wedge ball valve of Flood & Co., of Blackfriar's, which works well under high and low pressures, and with hot or cold-water. The loose ball valve of Guest and Chrimes, of Rotherham, working on a metal seat by means of a screw so threaded that it is opened and shut by very small variations in the level of the water in the cistern, is also deserving of notice.

878.—*How may the water of small houses be used to flush drains?*

In small houses the water which is discharged into the soil drain is sufficient to remove its contents, but otherwise this can be accomplished by a *flush tank* which periodically discharges the whole of its contents into the drain. This tank consists of a cistern which contains a large outer tube closed at the upper end and inverted over a small inner tube thus forming a siphon. The inner tube is open at the top, and passes vertically down through the tank to dip slightly under the surface of water in a chamber below the tank, the water in this lower part being kept at the required level by means of a weir, practically forming a D trap. As the water rises in the tank from the discharge into it of a tap of a drain, some of it eventually runs over the top of the inner tube, air is forced through the water and cannot return, siphon action is started, and the whole contents of the tank are emptied into the drain.

879.—*What are the conditions of water which affect the question of the materials of cisterns in houses? How is water in* *house cisterns likely to become polluted? What precaution should be taken to guard against such pollutions?*

It is generally considered that the conditions of water affecting the materials of which cisterns are constructed are:—1. Its softness or hardness. 2. Water containing nitrates, chlorides, and organic matter, having a tendency to dissolve lead, should not be stored in cisterns lined with that material. 3. Water containing substances such as salts of nitric or nitrous acid, or large quantities of organic matter, dissolve portions of zinc, therefore it is advisable to avoid its use. 4. It should be remembered, however pure the water may be, if left in contact with new bright lead, the atmospheric influence is such as to cause oxidation, or, in other words, a coating of leaden rust, which dissolves in water, and may be the cause of lead poisoning.

Water in house cisterns is polluted in various ways. Sometimes the cisterns are placed in out-of-the-way places and difficult of access for cleansing purposes. They are thus left, seldom or never cleaned out,causing the water to be contaminated from the uncleanly state of the cistern. They are found without covers, and therefore open to all sources of contamination. They are often fixed without due regard to ventilation, thus any foul gases with which the air may be charged, are the more readily absorbed by the water. Vermin is occasionally found in cisterns not properly protected, and perhaps not discovered ere the last stage of decomposition has set in, thus causing an examination of the cistern to discover the evil.

Water in cisterns is also affected by the materials used in the construction of same. To guard against such pollutions, slate cisterns are advisable, provided they are properly constructed. Let the cistern be protected with a properly constructed ventilating cover, and placed in such a position that it may always be easily accessible for cleansing purposes. And lastly, cleanse the cistern at least twice a year.

880.—*What are the most common sources of water-contamination in house cisterns?*

1. Sewer gases from the overflow-pipe passing down to closet or drain.
2. Accumulations of dirt take place from neglect.
3. Rats, mice, cats, etc., fall in and putrify.

881.—*How may the impurities of house-stored water be lessened to some extent?*

By fitting on to the house cistern, some form of specially made filter; so as to render the water ready for use on domestic delivery.

882.—*How is the water conducted to and from the reservoirs?*

In pipes.

883.—*Of what are the pipes constructed in both cases?*

The pipes are composed of iron, masonry, or earthenware, for the larger pipes or mains, the iron being sometimes tinned or galvanised, or lined with concrete, or pitched, or covered with a vitreous glaze; for the smaller pipes, iron, lead, tin, zinc, tinned copper, earthenware, gutta-percha, etc., are used.

884.—*What is the best material for water mains and all large pipes?*

Cast-iron. This is even the best material for small pipes, on the constant system on account of the high pressure which the pipes have to sustain.

885.—*What forms of aqueducts are in use?*

Open masonry channels, but chiefly cast-iron pipes.

886.—*How are these pipes laid?*

Two or three feet under the surface to protect them from frost. They are lined with pitch or some other material to prevent corrosive scouring. Valves and air vents are placed at intervals and at all bends or summits.

The aqueduct may be an open channel, but it usually consists of iron pipes buried two or three feet in the ground as a protection against frost. The pipe aqueduct may be lined with pitch or other anti-corrosive, and being water-tight, its course is not necessarily downward at all points. Means of access are provided at short intervals for cleansing purposes, and if its course is undulating, sluices are needed at the lowest points for scouring out *debris* and air vents at the summit.

887.—*What is the best material for mains?*

Cast-iron; nothing else can stand the pressure in the constant system.

888.—*What is the best material for sub-mains?*

Cast-iron.

889.—*Of what form of iron are water mains made?*

They are constructed of cast-iron, of a soft and tough quality. Great attention should be paid to moulding them correctly, so that the thickness may be exactly uniform all round. Each pipe should be tested for air-bubbles and flaws by ringing it with a hammer, and for strength by exposing it to double the intended greatest working pressure.

Cast-iron is at once comparatively cheap, durable, and innocuous; the water may, however, be fouled by defective caulking; Spence's metal employed by some companies is free from this objection, since no oakum or other caulking is required, as it is with lead joints. Cement joints are also safe, but liable to leakage or absorption of pollution from the soil.

890.—*What is the special objection against cast-iron mains?*

They are subject to much rusting and corrosion, especially when the water is soft.

891.—*By what rule may the strength be roughly estimated ?*

By the rule that the thickness of a cast-iron pipe is to be less than a mean proportional between its internal diameter and $\frac{1}{48}$ of an inch.

892.—*Give a more accurate means of estimating the strength than this ?*

The limit of safety being 6 times the working pressure the thickness divided by the direction equals the greatest working pressure or a foot of water divided by 12,000.

$$\textit{Thickness}\text{—Greatest working pressure} = \frac{\text{one } \textit{foot} \text{ of water}}{12{,}000}.$$

The capacity of pipes must be adopted to the greatest hourly demand.

893.—*How is the size of the main service pipe regulated ?*

The size of the main service pipe from the water company's main is usually fixed by the company. It must, however, vary with circumstances, such as distance, amount of storage, size of house, etc. Between the main and the first branch pipe a stop-cock should be fixed, so that in case of accident the water may be turned off entirely. Another stop-cock or valve is required by the London water companies to be fixed outside the house, for the use of their officers only. [It is also advisable in cases where there are several cisterns, and more especially where there is a constant service, to have a stop-cock fixed in connection with each ball valve, so that the water can be turned off from any one cistern without interfering with the others. In case of a cistern requiring to be cleansed, this arrangement will be found of service. Joints in lead water-pipes should always be of the form known as a wiped joint. This joint is formed by inserting the end of one pipe, the edge of which has been previously rasped down, about ¼ to ¾ of an inch into the other. The joint is then covered with molten solder until a sufficient thickness is obtained, when it is wiped round with a special kind of cloth. This kind of joint is the most durable for ordinary purposes of plumbing; for pipes for conveying water it is, indeed, the only one permissible under most water companies' regulations.]

The thickness necessary for an iron pipe to sustain a given pressure is found by the formulæ—

$$\frac{\text{thickness}}{\text{diameter}} = \frac{t}{d} = \frac{P\ 1}{12000}$$

where P is pressure in feet of water, and t the factor of safety is 6 times the working pressure or 12,000, or in other words, the breaking load is six times the working load.

94.—*What should be the minimum thickness of cast-iron pipes ?*

The thickness of a cast-iron pipe should never be less than ⅜ inch, they are usually in lengths of 9 feet, exclusive of the faucet.

895.—*What is the length of pipe required for large towns?*

About a mile of pipes for every 2,000 or 3,000 inhabitants.

896.—*Does the cost of pipes increase uniformly with the quantity?*

The cost of the pipes through which the water is conveyed does not increase uniformly with the quantity; but only as the $\frac{2}{5}$ power of that quantity. If the cost of conveying 100 gallons be A, the cost of 200 gallons will be $2\frac{2}{5}$, A = 1·32 A and that of 300 gallons will be $3\frac{2}{5}$, A = 1·55 A. That is if 100 gallons can be conveyed for £1 three times that quantity can be conveyed for 1/4—and so on in the same proportion. The cost of conveying a determinate quantity of water through pipes decreases as the total quantity increases. There is always a great advantage in concentrating the quantity of water to be conveyed instead of dividing them among a number of smaller mains.

897.—*How may we calculate the discharge from water-pipes?*

By first finding the velocity of the discharge, which is,

$$\frac{\text{Head} \times \text{diam. of pipe}}{\text{length of pipe}}$$

in feet, then taking the square root of the result, multiply this by 50 the product being the velocity in feet per second. When the velocity × the area of the pipe, in feet, is equal to the number of cubic feet discharged per second; and this multiplied by 6·25 = number of gallons. [The area of the pipe is equal to the square of the diameter × ·7854.]

898.—*Give an example of this.*

Head, 32 feet.
Diam. of pipe $\frac{1}{2}$ foot.
Length of pipe 100 feet.

$$\frac{32 \times \frac{1}{2}}{100} = \cdot 16.$$

Square root of ·16 = ·4 and ·4 × 50 = 20.
Velocity therefore is = 20 feet per second.
Let the sectional area be = $\frac{1}{5}$th of a foot.
Then $20 \times \frac{1}{5} = 4$.
Discharge therefore = 4 cubic feet;
and 4 × 6·25 = 25.

That is 25 gallons per second; this is in straight pipes.

899.—*By what other formula may we calculate the volume of water discharged from a pipe?*

By the formula:—

$$39{\cdot}27\sqrt{\frac{hd^5}{l}} = \text{V in cubic feet per second.}$$

Where h = head of pressure,
d = diameter of pipe.

900.—*Give an example of the working of this formula ?*

The diameter of a pipe is 1 foot, the head of the flow 9, and the length of the pipe 9,000 feet; what is the volume of discharge?

$$39{\cdot}27\times\sqrt{\frac{9\times1}{9000}}=39{\cdot}27\times\sqrt{\cdot001}=1{\cdot}242 \text{ cubic feet.}$$

901.—*Calculate diameter of a pipe necessary to convey water to a town of 2,000 inhabitants from a reservoir 5 miles distant, with a head of water of 50 feet.*

With 30 gallons per head 60,000 gallons are needed every 24 hours or 42 gallons a minute.

One of the formulæ given for this is :—

$$\frac{\text{[illegible]}}{784\ H}=\frac{\text{[illegible]}}{794\times50}=1180$$

$d =$

$d = 4$ inches (approximately) which is the diameter of the pipe required.†

902.—*Where are cast-iron pipes particularly suited ?*

For conveying small quantities of water from great heights.

903.—*By what formula may we calculate the required thickness of a pipe ?*

Multiply the pressure in pounds per square inch by the diameter of the pipe in inches, and divide the product by twice the tensile resistance of a square inch of the material of which the pipe is constructed.

When water is brought into a town from a considerable distance, whatever be the sources, the conduit or channel in which it is conducted, has to be of a certain discharging capacity, which is reduced to a minimum if it be made according to the average demand, the conduit being of course in constant operation. But it must be remembered that the water is not consumed in the town at a uniform and constant rate. In most cases the draught upon the mains from 8 o'clock in the morning until noon is from two to two and half times the average consumption.

904.—*What should be the dimension of the main conduits in towns ?*

As the greatest hourly demand for water is about double the average hourly demand, the main conduits supplying a town must have double the discharging capacity which would be required if the hourly demand were uniform.

905.—*How might the difficulty of great demand at particular times be met apart from using large-sized mains ?*

The additional expense in piping which would be thus entailed is sometimes so great, that distributing basins or town reservoirs are instructed to supply certain districts.

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* The fifth root may be found by logarithms, and with reference to this question, divide logarithm 1188 by 5 and re-convert.

† For definition of *d*, G, L, and H, see No. 910.

906.—*Are mathematical calculations as to thickness of pipe required absolutely correct?*

Not quite; for in calculating the requisite thickness of a cast-iron pipe under given conditions, it must be borne in mind that, whatever care is taken, it is impossible to keep the core always perfectly central, and that therefore a pipe will have an excess of metal on one side, and a corresponding defect on the other. And as the strength of a pipe depends upon its weakest part, due allowance must be made for this defect. When all the imperfections to which a cast-iron pipe is liable are taken into consideration, it will be seen that, to obtain perfect security from accident, the factor of safety must be taken large. Many engineers take it at six, others at ten, the latter we think the most prudent course. The passage of heavy traffic along the roads, and the turning off of cocks frequently bring a sudden strain upon a pipe, which the nature of its material is ill-adapted to bear. It is a common practice for Engineers to calculate the weight of a pipe of the requisite thickness and to specify the weight rather than the thickness, leaving the founder to fix that for himself, which long practice enables him to do with considerable precision. Absolute correctness, of course, cannot be obtained, and a margin of 1 lb. to an inch either way is usually allowed.

907.—*How may the weight of a cast-iron pipe be found?*

The weight of a cast-iron pipe may be found by multiplying the cubical contents in inches by ·26 lbs. the weight of a cubic inch of cast-iron, or the weight of a yard may be determined by the following formula:—

$W = 7{\cdot}35\,(D^2 - d^2)$, in which D represents the outside, and d the inside diameter in inches. The weight of two flanges is equal to about 1 foot of pipe, the faucet adds from $\frac{1}{20}$ to $\frac{1}{10}$ of the weight of the pipe. The usual length of a cast-iron pipe, exclusive of the faucet, is 9 feet. Suppose now 10 in. pipes are required, capable of bearing safely a pressure of 400 feet of water. We have shown that in this case the requisite thickness is ⅝ in. The outer diameter will therefore be 11¼ in. Hence the weight of the whole pipes will be $3 \times 7{\cdot}35\,(126{\cdot}56 - 100) \times \frac{22{\cdot}05 \times 26{\cdot}56}{15} = 624$ lbs. taking the weight of the faucet as $\frac{1}{15}$ that of the pipe. The weight specified to the founder will thus be 5 cwt., 2 qrs., 8 lbs. And allowing a margin of 1 lb. to the inch of diameter, the pipe delivered may be anything between 5 cwt., 1 qr., 26 lbs., and 5 cwt., 2 qrs., 18 lbs.

908.—*What should be the size of the branch pipes ?*

The ratio of the diameters of branch pipes varies as the fifth root of the volume squared.

909.—*In large towns what should be the total length of the distributing pipes ?*

Approximately, distributing pipes may be taken at 1 mile per 3,000 persons.

910.—*What should be the maximum velocity of water in a pipe or main ?*

Three feet per second.

911.—*How may we calculate the delivery of water through pipes ?* *

By the following two formulæ:—

$$(1)\quad G=28\sqrt{\frac{d^5\times F}{L}}=\text{ supply in gallons per minute.}$$

$$(2)\quad H=\frac{G^2\times L}{784\,d^5}=\text{ head in feet to overcome friction.}$$

Where, d = diam. in *inches*.
G = supply in *gallons* per *minute*.
H = total head above point of discharge in *feet* (or fall in a given length, L).
L = length in feet (or distance from source to delivery).

For example, calculate the diameter of a pipe necessary to convey water to a town with a population of 2,000 from a reservoir five miles (26,400 feet) distant, with a head of water of 50 feet.

Allowing 30 gallons per head, 60,000 gallons are required for 24 hours, or 42 gallons per minute

From formula (2),

$$=\frac{G^2\times L}{784\,H}=\frac{1764=26400}{784\times 50}=1188$$

$$\therefore d=\sqrt[5]{1188.}$$

The fifth root may be found by logarithms (divide log. 118895 and re-convert); fifth roots are also given in Molesworth's and other Engineering tables d = 4 inches (about) = diam. of pipe required.†

912.—*Are hydraulic formulæ accurate ?*

For all practical purposes they are approximately so, but as they are the result of mere experiment they vary within wide limits.

913.—*What is the resistance which a 12-inch pipe offers ?*

The resistance which a pipe offers to the internal pressure tending to burst it, is equal to the cohesive strength of its two sides, and the effective area of that pressure is the internal diameter of the pipe. If the tensile strength of cast-iron is taken as 15,000 lbs. to the square inch, the thickness of a pipe to be subjected to water pressure will be given by the formula.

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* Cambridge University Sanitary Science Paper, 1887.

† D. S. DAVIES, M.B.D.P.H., Camb., in the *Medical Annual*, 1890.

914.—*What is the effect of friction in pipes?*

The effect of "friction" is = "loss of head"; the flow is retarded and the water will not spout up to the same height as at the source; the effect of friction is greater the smaller the pipe.

915.—*What effect have bends and curves in pipes?*

Bends and curves likewise retard the flow. In an angle of 40° the "loss of head" is equal to ¼th of the original head; at an angle of 60° it is = one-third and at an angle of 90° it is almost = the original head.

916.—*How do curves affect the flow in pipes?*

"Curves" retard the flow very much. In an angle of 40° a loss of head is = ¼th of the original head.

An angle of 60° it is = one third.

An angle of 90° it is almost = the original head.

917.—*What is the result of this?*

That in such cases the water will not rise so high as the original head, if it can get out before; but still, if conducted in a pipe, it will rise to the original height.

918.—*Of what else may pipes be constructed?*

Pipes of artificial stone are now made. Iron is the best material for the larger pipes, and iron or non-metallic substances for the smaller pipes.

Cast and wrought-iron pipes can be used, and Mr. Rawlinson now orders no others. The iron can be glazed internally. Iron pipes coated inside with Angus Smith's bituminous varnish are now used a good deal, but the tarry taste lingers in the water a long time. Copper-tinned and block-tin are also employed, and both are excellent, but are rather expensive. In some cases the tin is eaten through, but this is not common, except with well-waters containing nitrates.

The iron can be glazed internally. Copper-tinned and block-tin are also employed, and both are excellent, but are rather expensive. In some cases the tin is eaten through, but this is not common.

919.—*What is required in summer months as regards the streets of most larger towns?*

It is necessary during the summer months to distribute water over the streets in order to mitigate the inconvenience arising from clouds of dust; to cool the atmosphere, and to assist in flushing the drains. Hydrants, which can be also used to communicate with fire-hose or stand-posts, are therefore attached at certain intervals to the mains; and in estimating the quantity of water required in any particular town, the quantity required for fires and street-watering must be taken into account.

920.—*In arranging a main pipe from pumps, what should be the sectional capacity of the pipes?*

Sufficient to allow of the velocity in the main pipe not exceeding 3 feet a second, as friction increases in proportion to the velocity, as is shown by the law governing the delivery of water from pipes under pressure.

921.—*What precautions should be adopted as regards covered reservoirs and tanks, and supply-pipes?*

Covered reservoirs and tanks should be ventilated, and all supply-pipes arranged in such manner as to allow of easy inspection and subsequent repairs. Stop taps should be placed between the main and the building in all cases, so as to allow of isolation of any line of service pipe for repairs. House service tanks service pipes ought to be fixed so that the rooms cannot be flooded in case of leakage or overflow, and ready means of access to all tanks and cisterns must be provided to allow of inspection, cleansing, or repairs. Up-bends should not be formed on lines of main pipes or on service pipes If up-bends are inevitable, air valves have to be provided to let out the air at the up-bends. Bends at right angles on pipes are to be avoided, and the pipe brought round in a curve instead.

922.—*What is the best form of covered conduit with uniform flow of water?*

Circular.

923.—*What are the essential requirements as to the construction of iron pipe?*

Uniformity of thickness, freedom from flaws and air-bubbles.

924.—*What should be the position of street mains?*

In wide streets, or where the traffic is extensive, there should be a service pipe on both sides, so as to make the house pipes short, and to render the service pipes accessible without interfering with the traffic.

925.—*How far does the presence of phosphorus in iron affect the properties of the iron?*

The presence of phosphorus in the iron renders it brittle, and very liable to fracture; this quality is technically known as *cold short.* Cold short iron should never be used for pipes. The presence of arsenic, on the contrary, is said to improve the quality of iron. It is perhaps scarcely necessary to state that castings for pipes must be kept free of scoria and air-bubbles. The presence of the latter may often be detected by sounding the pipe in every part with a hammer. Whenever an air-bubble is detected, or even of its presence is suspected, the pipe should be thrown aside as dangerous if it is subjected to considerable pressure. To prevent air-bubbles remaining in the metal, pipes are often cast with a head, that is, with a mass of metal above that requisite for the pipe itself. This head compresses the mass below, and receives the air-bubbles which ascend into it. When the casting has cooled, the head is cut off. Pipes produced in this manner are stronger and much more trustworthy than those cast without a head.

926.—*What is the usual means of constructing long mains ?*

A long main is usually composed of pipes of different sizes, and in computing the discharge of such mains, the head for each must be separately calculated, and the total sum taken. Suppose for example, we have a main consisting of 500 yards of 8 inches, 200 yards of 7 inches, and 100 yards of 6 inches pipes, through which it is required to discharge 200 gallons a minute For the friction of the 8 inches pipe we require a head of 2·50 feet, for that of the 7 inches a head of 1·96 ft., and for that of the 6 inches a head of 2·10 ft. The total head requisite for the whole main is $2·50+1·96+2·10 = 6·56$ ft. To this must be added the head due to the velocity of entry, and if there are bends, that due to changes of direction.

927.—*What are the causes of waterflow in pipes ?*

The head due to friction and to the resistance offered by bends and the head due to the velocity of entry. In long mains, this quantity is so small a proportion of that due to friction that it may be neglected without sensible error; but in short pipes, it may be much greater than the head due to friction, and therefore, in such cases, it cannot, of course, be neglected.

928.—*What resistance do the walls of iron pipes offer to the passage of a water ?*

In every system of town water-supply or drainage, the friction of the water in the long succession of pipes through which it is conveyed, causes a considerable diminution in the quantity discharged under a given head of pressure, and the extent of this diminution, or, as it is usually termed, the *loss of head*, must be ascertained before the diameter of the pipe requisite to convey a certain volume of water can be determined. It has been found by experiment that this friction depends on the velocity of the water and the diameter of the pipe, and that it increases very rapidly with the velocity.

929.—*In what way may water be polluted in the mains?*

Pollution would occur either through defective joints in the mains themselves, or by the open ends of the house service pipes which they supply. It would happen from either cause at such times as the mains are partially empty, as, for instance, when, under the intermittent system of supply, the water has been "turned off," and the draught of water from the lower part of a main has created a partial vacuum at the upper end. At such times sewage escaped from the sewers, and coal gas from leaky gas pipes, have been drawn through bad joints in the mains, and filth from privy pans, and even blood from slaughter-houses, besides foul air from various sources, have been sucked in by the service pipes.

930.—*What precautions are necessary to prevent such pollution?*

The adoption of the system of "constant service" (carried out in its integrity) both diminishes risk and renders the detection of possible sources of pollution more easy. By waste-water meters and other appliances, defects in the mains can be localized and amended; the disconnection of water-closet from house service by "service boxes" for the prevention of waste, the stronger pipes and better fittings rendered necessary, all tend to diminish risk of pollution.

Water may be fouled in the "dead ends" of mains little used by the constant deposition of iron rust and suspended impurities. But in a well-devised system the pipes will be so laid as to maintain a constant circulation throughout the system or section of a system, and any "dead ends" unavoidably retained, frequently flushed.

931.—*In an open channel, what is the loss of head of the water?*

In an open channel the loss of head is the actual fall of the surface of the water.

932.—*Where is in-suction likely to arise?*

Buchanan has shown that there is danger of in-suction if a perforation exists in a descending pipe, and especially at a point of constriction, even if the pipe is constantly full.

933.—*Is there any other risk to a public water-supply?*

Yes, that of the direct connection of water-mains with closet-pans. In Warwick and Rugby, Dr. Whitelegge found that nearly one-fourth of the closets were flushed directly from the main by means of stool-cocks, and on his recommendation the whole of them were disconnected. As a consequence of this precautionary measure, although the water-supply was made intermittent in Warwick during three months of last year owing to continued drought, the town continued entirely free from enteric fever, nor was there any excess of diarrhœa.

934.—*What is the construction of the filtering block of "silicated carbon"?*

The filtering block of the Silicated Carbon Company consists of 75 per cent. of charcoal and 22 of silica, with a little iron oxide and alumina. It is cemented into a vessel which it divides into two chambers, the one containing the filtered and the other the unfiltered water. This filter is found to work very efficiently, and with a little care retains its properties for a long time. The filtering material of the *magnetic carbide* filter is prepared by heating hæmatite with sawdust, and has all along been highly commended.

935.—*What are distributing conduits and mains and how are they constructed?*

Distributing conduits and mains convey the water to all parts of the district, and pass beneath the streets. They are similar in construction to the main aqueducts, and have "scouring valves" at all dead ends in order to wash out sediment. They should be kept as far as possible from the sewers and gas mains. Hydrants are provided at short intervals for use in case of fire.

936.—*What qualities of earthenware pipes are in use?*

They are of various qualities as to texture, from a porous material like that of red bricks, to a hard and compact material, which is glazed to make it water-tight. They are made of various diameters from 2 inches to nearly 3 feet, and in lengths of from 1 foot to 3 feet. The harder kinds have considerable tenacity, and are capable of bearing the dead pressure of a high column of water; but they are so easily broken by sharp blows and sudden shocks that it is not advisable to expose them to high pressures in situations where their bursting might cause damage or inconvenience. Hence their chief use is as *small covered conduits* for purposes of drainage. Their joints are most commonly of the spigot and faucet form, being made water-tight, if necessary, with cement, or with a butuminous mastic. Another form, very useful to facilitate laying and lifting, is the *thimble-joint* The lengths of pipe are plain hollow cylinders. and the thimble is a ring embracing and loosely fitting the adjoining ends of a pair of lengths. Sometimes the thimble is in two semi-circular halves; and sometimes each pipe has on one end a half-faucet, which is laid downwards; the end of the adjoining pipe rests in the half-faucet, and the joint is completed by a half-thimble above. Curved and acute-angled junction-pieces are made; so also are right-angled junction-pieces; but these last should never be used.

937.—*What is Dr. Buchanan's opinion in regard to in-currents in pipes?*

He stated: "I find (1) the lateral in-current is freely produced when the water-pipe is descending, and when the pipe beyond the hole is unobstructed; (2) if the force of water-flow in a descending pipe be moderate, a moderate degree of obstruction beyond the hole does not prevent the in-current; (3) in horizontal pipes of uniform calibre, when the flow is strong, or the pipe beyond the hole is long, or when the end of the pipe is at all turned upwards, the in-current does not take place; but (4) momentary interference with flow *a tergo*, or momentary reduction of obstruction *a fronte*, allows of a momentary in-current through the hole; (5) in-current through a lateral hole takes place with incomparably greater ease when the hole is made at a point of constriction of the water-pipe."

938.—*Is the constant service free from the possibility of in-currents?*

Even with a constant supply there appear to be certain dangers depending upon possible in-currents from leaky mains, especially when these are in juxtaposition to sewers or drains which have hitherto escaped the notice of engineers.

939.—*Should pipes be tested before being used?*

All pipes before being used should be tested by hydraulic pressure up to three or four times the head they will have to bear. They should also be carefully rung all over the surface with a hammer to detect the presence of air-bubbles. As to appearance, they should show on the outer surface a smooth, clear and continuous skin. When broken, the surface of fracture should be of a light bluish-grey colour and close-grained texture, and both colour and texture should be uniform. It may be remarked, however, that the colour will be somewhat lighter, and the grain closer near the skin, in consequence of the chilling which takes place there in casting. The iron should be soft enough to be slightly indented by a blow of a hammer on the edge.

940.—*What are the chief points in connection with mains?*

That the material of which they are composed should not defile the water, that they are of sufficient strength and size, and that they are water-tight.

941.—*In the constant system, what bit of apparatus should be between the main and the house pipe?*

A "screw-down tap" of good make to be placed at the entrance of the pipe into the house. The tap should be in the care of the occupier so that he might turn off the water in case the pipe bursts, or empty it during frost.

942.—*Describe the necessary condition of the distributing conduits and other communications?*

The distributing conduits consist of cast-iron pipes, and are coated, like the aqueduct pipes, with pitch, or Dr. Angus Smith's varnish, to preserve them from corrosion. The same details with regard to sluice-cocks and stop-cocks are observed in the different bends of the tracks, with this addition, that the dead ends or terminations of the branch and main conduits are supplied with scouring valves, through which stones and sediment can be washed. In wide streets, or in streets with much traffic, there is generally a service pipe for each side, in order that the house pipes may be as short as possible, and may be accessible without disturbing the traffic. The house service pipes are usually made of lead, and though they are liable to be acted upon by some waters, the readiness with which they can be adapted to all the bends and curves rendered necessary in carrying the piping to different floors of houses, gives them a preference to all other kinds of metal pipes. The waters which act most on lead are the most highly oxygenated, and those which contain organic matter; those which act least on it contain carbonic acid, calcium carbonate, and calcium phosphate. Polluted shallow well-waters are especially dangerous in this respect, because they act on it violently and continuously, and hence leaden pump-pipes should never be used. Various means have been proposed to protect the lead from corrosion, such as coating with bituminous pitch or with coal tar; but when the quality of the water renders lead pipes objectionable, cast and wrought-iron pipes make the best substitutes, or composite cylinder pipes may be used. These pipes consist of a separate tube of pure block-tin encased in lead, and the union of the two is so perfect that no amount of torsion will separate them.

943.—*Does coating the interior with tin protect these pipes, and overcome the difficulty of rusting?*

It does not; washing the interior with tin is not successful, since the thin layer of tin gives at every bend, and the galvanic action set up by the two metals hastens their solution.

944.—*May the same be said of block-tin pipes?*

No, block-tin pipes cased in lead (Haines' patent), and those made by Messrs. Walker, Parker & Co., on the contrary, resist any amount of torsion, and are a perfect success; care must, however, be taken in junction that no part of the lead be exposed to the contact of the water. Professor Emerson Reynolds states that an alloy of lead with 3 per cent. of tin is not attacked by water, and is used with good results in Dublin and Glasgow. According to Dr. Parkes, zinc pipes, into the composition of which lead enters largely, are rapidly dissolved; and lead pipes if used should not be bent against the grain so as to expose the structure of the metal.

945.—*What is the office of distributing conduits and mains?*

They convey the water to all parts of the district, and pass beneath the streets. They are similar in construction to the main aqueducts, and have "scouring valves" at all dead ends in order to wash out sediment. They should be kept as far as possible from sewers and gas mains. Hydrants are provided at short intervals for use in case of fire.

946.—*Should there be any openings in water mains?*

Yes; (*a*) scouring valves in valleys, to get rid of any sedimentary matter; (*b*) taps about every half mile to permit of repairs; (*c*) valve cocks at the summits of hills and eminences, to give exit to any air that might collect.

is less. Each pipe leaving the cistern, where there is one, or supplying any separate system of taps, should be fitted with one of the latter kind, that the entire water supply may not be cut off when any part is undergoing repairs.

1051.—*What is Eytelwein's formula?*

$$W=4.71\sqrt{\frac{D^5 H}{L}}$$

$$D=0.538\sqrt[5]{\frac{L W^2}{H}}$$

Where D=diameter of pipe in inches
H=head of water in feet
L=length of pipe in feet
W=*cubic feet* of water discharged per minute.

1052.—*How may this formula be stated as a problem?*

As follows:—If water with a head of H feet flows through L feet of pipe of D inches in diameter, what would be the discharge W in cubic feet per minute?

1053.—*What is the use of Eytelwein's formula?*

To calculate the size of pipes and delivery of water through pipes.

1054.—*Why is air in water pipes objectionable?*

(*a*) Because even a small quantity of air is liable to stop the flow of water unless there is great pressure in the pipes, and (*b*) the air might be conveyed to the house-pipes, where this is far more likely to occur.

1055.—*In general terms what should be the relation of the water pipes to the gas and sewer pipes?*

They should be as far as possible from gas and sewer pipes; for leaky mains frequently have great suction power, especially where the supply is on the intermittent system and with such suction there is great danger to the absorption of sewer gases and gas itself.

1056.—*Why should water pipes be placed deeper than gas-pipes?*

Because gases tend to ascend: should any leak occur in the gas-pipes the water would be out of danger. [The same may be said with regard to *sewer gases*. Gas and water pipes should not be laid in the same trench, or alongside any drain-pipe, because these small pipes have frequently to be laid bare, and this might endanger the soundness of the drain.]

1057.—*What other arrangements besides those for domestic supply are provided on the service pipes?*

In addition to the arrangements for domestic supply, outlets or hydrants with valve-cocks are provided on the service pipes of all large towns, at regular intervals, in case of fire, and for supplying water to flush the gutters and water the streets.

1058.—*What does the system of perfect clarification of water include?*

Three divisions, *viz.:* the settling basin, the filter-bed, and the clear-water basin.

1059.—*What should be the capacity of filter-beds?*

Experience indicates that the flow through a filter-bed should not exceed the rate of 17 feet lineal per diem, or be reduced by silting of the sand layer to less than 6·5 feet per diem. It must not be so rapid as to reach the sand grains or clay particles or the intercepted fibres through the bed, or its whole purpose will be entirely defeated.

A rate of about one-half inch per hour, or twelve lineal feet per diem, when the filter is tolerably clean, is generally considered the best. This gives the filter-bed a capacity of twelve cubic feet, or 89·76 gallons per square foot of surface per twenty-four hours, and requires, in work, about 12,000 square feet of filtering surface for each million gallons of water to be filtered per diem.

1060.—*How often should the filter beds be cleaned?*

The filter-beds upon the English streams require cleaning about once a week, when the rivers are in their most turbid condition, and ordinarily once in three or four weeks.

1061.—*How is the cleaning process carried out?*

The process of cleaning consists of removing a slice of about one-half inch thickness from the surface of the fine sand layer, and the stirring or loosening up of the sand that is packed hard by the weight of the water, when the clogging of the filter prevents or hinders greatly its flow. This requires the water to be drawn off from the bed to be cleaned, and of course, puts the portion of filter area being cleaned out of service. According to the usual practice, the water is drawn down only about a foot below the sand surface for the cleaning; but there is a great advantage, though an inconvenience, in drawing the water entirely out of the bed, for this admits the air to oxidize the organic matters that are drawn into the filter, which is of great importance.

To provide for cleaning, the required area for service should be divided into two or more dependent beds, and then one additional bed should be provided also, so that there shall always be one bed surplus that may be put out of use for cleaning.

1062.—*How is water filtered on a large scale for town supply? State under what circumstances such filtration is likely to purify the water sufficiently for health.*

Water for the supply of large towns, is filtered by passing through mechanical filters constructed somewhat as follows:—The water is sometimes first passed through a subsiding tank where the solids are allowed to settle, is then discharged into a filtering reservoir. The bottom layer of the filtering medium consists of clean gravel (gauged to about the size of a walnut) from 1 foot to 1 foot 3 inches deep; the second layer gravel broken to a gauge of the size of horse beans, about 6 inches deep; the third layer gravel broken to a gauge the size of peas, same depth as before, and fourthly a layer of gravel, 6 inches deep, size of buckshot. This is topped with from 2 feet to 3 feet of clean sand, and upon this surface the water is distributed, whence it percolates through the sand and gravel into brick-collecting drains and thence into the pure water reservoir or pump wells. To efficiently filter the water it should not be allowed to pass the filter quicker than at the rate of about fifty gallons per superficial foot of area of sand surface in twenty-four hours, and require frequent cleansing, which is done by removing a small quantity of the top layer of sand, which is thoroughly washed and again used after exposure to atmospheric influences. It should be remembered that the filtering medium must always be *thoroughly clean* to allow of efficient action. Water, either river or well, passed through such a filter as above described, should be equal to that supplied to the metropolis of London, which has to pass the test required by Act of Parliament and the examination by the Government Water Examiner.

1063.—*What should be the thickness of stones, and what materials are placed above or superficial to it?*

This layer of broken stone must be 24 inches thick to cover efficiently the pipe drains. Upon this layer of stone properly levelled off, from 18 to 24 inches of gravel is laid. This gravel is usually screened into two or three sizes, the larger of walnut size, the next of the size of a hazel nut, and the third between that and pea size. The largest size lies upon the broken stone, the smallest size at the top, the layers 6 inches thick each. Over this gravel there is laid not less than 30 inches of fine sharp sand, screened to ensure the requisite degree of fineness and uniformity. The lower 12 inches may be a little coarser than the upper stratum of 18 inches, but it is important that the two layers should be of uniform fineness and quality throughout, otherwise there will be danger of the water passing through more rapidly at one point than another. The whole depth of these materials amount to five feet eight inches.

1064.—*Discuss the question of the quality of sand used in public water-supply filters.*

A uniform sized grain of sand or gravel offers greater percolating facilities than mixed coarse and fine grains. The proportion of interstices in uniform grains is from thirty to thirty-three per cent. of the bulk, and the larger the grains the larger the interstices and the more free the flow. On the other hand, the smaller the grains, or the more the admixture of smaller with dominating grains, the smaller the interstices, and the less the flow, but the more thorough the clarification and the sooner the pores are silted with sediment. If there is much fine material mixed with the gravel, water will percolate very slowly, and a larger proportional infiltration area will be required to deliver a given volume of water. Provision is made for the flowing on of the water so as not to disturb the fine sand surface. This inflow duct is often arranged in the form of a tight channel on the top of the covering of the central gathering drain, and the water flows over its side walls, during the filling of the basin, to right and left, with slow motion. The depth of water maintained upon the filter-bed in four feet or more, according to exposure and climatic effects upon it.

1065.—*What are the settling and clean-water basins?*

When the water is received from a river subject to the roil of floods, it should be received first into a settling basin, where it will be at rest forty-eight hours or more, so that as much as possible of the sediment may be separated by the gravity process, before alluded to. Its rest in large storage basins prepares it very fully for introduction to the filter-bed, which is to complete the separation of the microscopic plants, vegetable fibres, and animate organisms, that cannot be separated by precipitation. [Since the domestic consumption of the water at some hours of the day is nearly or quite double the average consumption per diem, the clarified water basin should be large enough to supply the irregular draught and permit the flow through the filter to be uniform.]

1066.—*When should the entire sand surface be renewed?*

When the repeated parings from the surface have reduced the top fine-sand layer to about twelve inches thickness, a new coat should be put on restoring it to its original thickness. If good fine sand is difficult of procurement, the parings may perhaps be washed for replacing with economical result. This is sometimes accomplished by letting water flow over the sand in an inclined trough of plank, having cleats across it to intercept the sand, or by letting water flow up through it in a wood or iron tank. In the latter case water is admitted under pressure through the bottom of the tank, and the sand rests upon a grating covered with a fine wire cloth, placed a short distance above the bottom of the tank. The current is allowed to flow up through the sand and over the top of the tank until it runs clear.

1067.—*What should be the maximum speed of vertical descent?*

Not much above 6 inches per hour.

1068.—*What is a water meter?*

It is a contrivance for measuring or registering the supply of water passing through a pipe or channel.

1069.—*What is a water module?*

An agent for regulating the supply of water passing into a channel or into a pipe, which makes it practically constant, although both the amount of water, and the pressure in the main canal, main pipe, or reservoirs, supplying the branch pipe may be variable.

1070.—*Describe the forms of water meters.*

There are two kinds of water meters, the *positive* and the *inferential.* Kennedy's and Frost's piston meters are examples of the positive kind. A piston works in a cylinder and is successively filled from the top and the bottom, and the number of strokes automatically recorded. The capacity and the piston being known, the result is so many measures of water.

The inferential meter is a turbine, an example of which is that known as Soimens; the flowing water causes a turbine to revolve, and from the velocity of current as measured by the revolutions of the turbine, the quantity of the water is "inferred."

1071.—*In order to prevent undue waste what apparatus are necessary?*

Water-meters are sometimes applied to the service-pipe supplying a group of houses to prevent excessive waste, and the landlord charged for the amount used; but as this plan induces the landlord to enforce a too rigid economy, it is not to be commended. The best water-meters are capable of registering exactly all amounts exceeding a flow of one gallon per hour; but when the water contains a considerable amount of undissolved impurities, and is badly filtered, they very soon become clogged up and fail to register anything like the quantity of water which may pass through them.

1072.—*What apparatus are used for the purpose of measuring waste? Who invented it and how is it employed practically?*

A meter for this purpose is called a waste water-meter, has recently been invented and patented by Mr. G. F. Deacon, C.E., the Borough and the Water Engineer of Liverpool, and tried at that town with considerable success. It is of the inferential class, and differs from ordinary meters in this—that it registers on a sheet of paper the variations in the flow of water at different hours of the day, and also the time at which those variations take place. These papers may be preserved for future reference and comparison. The meter consists of a vertical, hollow, truncated brass-lined cone, having within it a horizontal disc of the same diameter as the upper and smaller end of the cone. From the upper surface of this disc projects a rigid stalk suspended from a fine German silver wire, which passes through a hole in the hollow boss to a chamber above, where it is connected with a guided cross-head carrying a pencil or tracer, and suspended from a hand passing over a pulley supporting on the other side of the pulley a weight which always tends to draw the disc up to the top of the cone. The vertical motions of the tracer are recorded on a paper wrapped round the drum driven by clockwork. The difficulties attending the use of small stuffing boxes are removed by using a simple brass bush with a hole in it fitting the wire closely and the small quantity of water which passes between the wire and the sides of the whole rises in the hollow boss and passes away by the drain pipe. There is a brass diaphragm with perforations for equalising the flow of water, and a hinged and padlocked cover of the clock chamber, having a watertight India rubber joint; there is a second cover carried by a frame in the footway. The drum with its paper is easily lifted from the footstep after the hinged bearing has been raised.

If now the instrument be fixed on the line of a water main, and all the outlets closed, the weight will have raised the disc to the top of the cone, or zero point, and on a tap being opened beyond the outlet of the meter water will seek to pass through, and pressing upon the disc, drive it down to a larger part of the cone. The descent of the disc will cease when, by reason of the increased area of annular space between the disc and cone, the pressure on its upper surface is relieved and the excess of that pressure over pressure on the lower surface is exactly balanced by the excess of the weight g above the weight of the disc weighed in water, and the cross head weighed in air. This point at which the disc stops will be constant so long as the rate of flow is constant, and the rate of flow having been once ascertained by direct measurement will be measured in future by the tracer standing at the same point.

The clock chamber is perfectly free from any dampness arising from the water in the mains, but in order to ensure firmness of the paper diagrams it is desirable in damp weather to place within the chamber a small saucer containing sulphide of calcium, which absorbs any moisture after the lid is closed. Although not absolutely necessary, it is nevertheless most desirable for the efficient carrying out of the system, as well as for the proper control of the supply to each block of premises in case of accident, that there should be stopcocks on the communication pipes between the service main and each house, or groups of houses, under the control of the inspector without entering the premises.

When a meter is used for detecting waste in any district, it is fixed to the supply main at or near the point where it enters the district, and the number and probable requirements of the people to be supplied are ascertained. The meter is then read at intervals, and the time between the readings noted. The quantity passed between any two of the readings is thus known, and from the data then collected it may be easily calculated if an undue amount of waste is taking place. In Deacon's automatic water register all the water above the line is used, that below goes to waste. Hourly inspection enables the supervising authorities to localise points of waste.

1073.—*Discuss the question of waste in water-supplies.*

In all large towns supplied by public water-works, there is a very large amount of water actually wasted. The Chicago Board of Public Works, in their report of March 31st, 1875, estimate that "one-half of the water now pumped is wasted," and in the St. Louis Report for 1876 a calculation is made by the Engineer, Col. Henry Flad, from which it appears that the prospective cost to the city for a period of ten years, on account of waste, is over four million dollars.

A case is recorded as having occurred at Torquay, where a main about 14 miles long, composed of 14,267 yards of 10 inches, 10,085 yards of 9 inches, and 170 yards of 8 inches pipes, delivered only 317 gallons a minute with 465 feet head. An ingenious scraper, worked by the pressure of the water, was passed several times through the pipes, the result being a discharge of 634 gallons.

1074.—*What proportion of water runs to waste?*

The quantity of water which run to waste, however, frequently exceeds enormously that allowed for through ill-constructed fittings and carelessness. A quantity equal to that used is not uncommon, and in one case, where 7 gallons of water per head per day were actually used, 18 gallons ran to waste. The most effectual means of preventing such waste are, the establishment of a regulation or enactment, that domestic water-fittings shall be executed to the satisfaction of the Engineer or Manager of the Water-Works; the carrying out, as far as practicable of the system of selling water by measure to those who require it for other than ordinary domestic purposes, and the prevention of excessive pressure in the service-pipes from which houses are directly supplied.

The amount of water actually utilised in the houses of a town varies enormously. In the houses of the poor the actual amount used may be only 2 or 3 gallons per head daily. This meagre amount is not only, or even principally, due to want of personal cleanliness amongst the occupants, but is far more often due to the limited quantity of water at their disposal, when the supply is intermittent and has to be stored in cisterns or water butts, often of a size totally inadequate to the wants of the people who take their water from these receptacles. It has been estimated that in London 15 gallons out of that supplied per head daily thus run to waste in the soil. An enormous amount of leakage takes place from water companies' mains in many towns, from slight settling of the ground after laying, or from the vibration of heavy traffic causing fracture of the pipes and joints. The loss is especially great where the supply is constant and the mains always kept under pressure. As already stated this difficulty has been overcome by Mr. Deacon, who has invented a meter which can be used as a waste detector. One of these meters is placed on each district main; it registers the flow of water by day and night, and therefore the waste, for the water flowing through the main during the dead of night, is not used by the consumers, but is running to waste.

Having localised the waste to a special locality supplied by a district main, the exact spots where the leakages are taking place can be determined by the vibrations produced in the nearest house communication pipes, which can be distinctly heard on applying the ear to the pipe. By this system, to take one example only, the Lambeth Water Company has reduced its consumption from 34 gallons per head per day to 20 gallons, the quantity available to the consumer remaining the same.

If the spots at which leakage occurs could be known, the pipes could be easily taken up and repaired; this can now be done with facility, but the difficulty was previously to find where the leaks were. [In some towns it has been found that as much as one-half or two-thirds of the total water-supply leaks out of the mains into the soil. The greater part of the waste, however, very often takes place from the mains, before the water reaches the consumer.]

1075.—*What are the ways in which waste may be prevented?*

There are two general methods suggested for lessening the waste which occurs. One is to introduce a rigid system of inspection to detect all leakage from the pipes and from imperfect fixtures, and to prevent all unlawful use of the water. Such a system has been found to work admirably in some places, a notable example being in Liverpool, where, by meters invented for the purpose, it was possible to determine the amount of water flowing in small sections of the pipes, and thus to locate any considerable leak or to ascertain where an abnormal amount of water was being used or wasted. The second method is to supply all the water through meters, as is now done with that portion which is used by manufactories and other large establishments. The principal objection urged against the adoption of this method in the case of private families, is the fear that, by the use of meters, an economy of water would be effected among the very class of people where, for the general good of the community, it is important that water should be used freely. There is considerable weight to this objection, and, if meters are to be introduced into the cities, either a certain amount of water must be allowed free, and the excess charged for at an established rate, or else some other arrangement must be made for the benefit of the poorer classes, especially for persons and families living in tenement-houses. It is further to be said that the cheaper meters are not very reliable, and it is often possible to pass a considerable amount of water without its being registered, provided the water passes slowly. The question is, after all, one which must be settled by local considerations. In many places, where there is an abundance of water at command and where the rates are low, the expense and the attendant inconvenience would make it advisable not to introduce meters. In other localities, where the available water is limited in quantity, or where, without economy, the existing supply is likely to prove insufficient in the immediate future, or in places where the rates are of necessity high, the introduction of meters would be advisable. The waste in northern cities during the winter is enormous, as it is very common to leave the faucets open during the night, in order to prevent freezing. To remedy this waste it would not be impossible to insist that the service-pipes should be laid below the line of frost, and that in the houses it should be possible to shut off the water and drain the pipes whenever there is danger of freezing. Vigilant inspection would probably accomplish as much as the introduction of meters to check such waste.*

1076.—*What was Mr. G. Deacon's explanation as to the cause of waste and what apparatus did he invent to detect and prevent it?*

Mr. G. Deacon, in a very interesting and instructive paper, has shown that the loss on the constant system is due to causes over which the consumer has generally little or no control, and that it occurs for the most part before the water reaches him. It arises chiefly from leaks in pipes, drawn joints, and so on, and up to lately there were no means of detecting this in a way practically useful. By the introduction of his water-waste meter this is now done with the utmost precision and accuracy, so that in Liverpool the expenditure of water has been reduced from 33·5 gallons per head per diem to 13·3. This does not mean any restriction to the consumer; the supply is now absolutely constant, and the use unlimited. But it means that formerly the consumer used only 13 gallons at the outside, whilst 20 gallons went to pure waste. Mr. Louttit stated that the Lambeth Water Company was able by this means to reduce their expenditure from 35·09 to 15·28 per head. The general waste in London appears to be about 15 gallons per head out of a total of about 35 gallons. With such a system of checking, the main difficulties of a constant supply seem to be solved, even if every consumer used the full 25 gallons laid down as the necessary quantity†.

1077.—*How is the system of inspection of waste meters conducted?*

Between the hours of 12 midnight and 5 A.M. is the best time for working the system, as between those hours the consumption is most regular. The inspector begins by closing the stop-cock to a block of buildings, and noting the time at which this is done. On examining the diagram there will either be no change, at that time, in the steady night line, broken only by an occasional draught, or it will show by a vertical movement of the pencil, and a continuation of the steady line at a lower level, that only a reduction in the continuous flow has taken place and therefore the premises supplied by the pipe in question should be visited by an inspector on the following day. By closing all the stop-cocks it may be ascertained whether the mains are in a sound or a leaking condition.

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* GORDON BUCK'S *Hygeine and Public Health.*

† PARKES' *Practical Hygeine,* 7th Ed.

1078.—*Are house water meters advisable? Give reasons for your answer.*

They are not advisable and for these reasons:—

1. Because they tend to restrict the necessary use of water for purposes of cleanliness.

2. This restriction prevents proper flushing of drains and sewers.

3. The primary expenses of the fittings, as well as of the necessary inspections and bookkeeping. All these tend to defeat the ends in view.

A scanty supply means uncleanliness, domestic and personal, with its associated evils and diseases.

1079.—*What are the best means to prevent waste of water?*

a. Employment of the best fittings—the use of good screw-down taps.

b. Any theft of fittings should be a specific offence punishable by law.

c. The supplying company's inspecting staff should carry out their duties carefully and conscientiously.

d. To enforce the principle that all water pipes or waste pipes should terminate in such a way that they may be readily inspected —in this way waste may be easily detected and prevented.

CHAPTER VIII.

MECHANICS OF WATER SUPPLY.

1080.—*What is meant by Hydrodynamics?*

Hydrodynamics is the combined science of hydrostatics and hydraulics, the former of which treats of the pressure and equilibrium of liquids at rest, whilst the latter explains the laws relative to liquids in motion. [Liquids, or fluids in general, are considered incompressible and non-elastic, but readily adapted to useful purposes through flowing freely, by agitation and inequality of level, hence hydraulic machines are brought in to produce useful effects; and although the laws of hydrostatics and hydraulics are universally applicable to fluids in general, yet water being the most abundant in nature it is the fluid invariably had recourse to for purposes of motive power.

Fluids when confined exert a force equal in every direction, but when unconfined are subject to the same laws as falling bodies in general, modified by mechanical considerations and experimental results, so that through water rolling or falling by the force of gravity, the greatest amount of effect is produced, whether for turbines or water-wheels.]

1081.—*Define Hydraulics.*

That department of physical science which treats of motion, especially of water which in motion presents itself in four different ways:—as passing out of a reservoir; flowing in a bed; acting as a motor: and in a passive state raised by machines.

1082.—*What is meant by Static pressure in relation to water?*

The full pressure due to the head of water while standing at rest.

1083.—*What is meant by Hydrostatics?*

It is a branch of Natural Philosophy that treats of the nature, pressure, gravity and motion of fluids in general. This science is divided into two distinct parts, *viz.*, Hydrostatics and Hydraulics, the latter relates particularly to the motion of water through pipes, conduits, etc.

1084.—*Does the weight of a fluid body press equally in all directions?*

Yes; any vessel containing a liquid sustains a pressure on every portion of the vessel, equal to as many times the weight of the greatest height of that fluid as the area of that vessel is to the sectional area of the column. The amount of pressure sustained by walls, flood-gates, sluices, etc., for the retention of water, equals the amount of area exposed, multiplied by half the depth of the fluid, and by its weight in the same known terms of unity. One cubic foot of fresh water weighs 62·355 lbs.

1085.—*By what rule may we calculate the discharge of water from an orifice when the aperture extends to the surface of the fluid?*

Multiply the area of the opening in feet by the square root of its depth, also in feet, and that product by 5·1; then ⅔rds of the last product will equal the quantity discharged in cubic feet per second.

1086.—*By what rule may we calculate the discharge of water from an orifice when the aperture is under a given head?*

Multiply the area of the aperture in feet by the square root of the depth also in feet, and by 5·1; the product is the quantity discharged in cubic feet per second.

1087.—*Give an example of the working of the foregoing rule?*

Required the quantity of water in cubic feet per second discharged through an opening in the side of a dam or weir, the width or length of the opening being 6½ feet, and depth 9 inches, or ·75 of a foot.

Square root of ·75=·866.

Then $\frac{6·5 \times ·75 \times ·866 \times 5·1 \times 2}{3} = 14·3839$ cubic feet.

1088.—*What would be the quantity discharged through the above opening under a head of water 4 feet in height?*

Square root of 4=2, and 2×5·1=10·2 feet, velocity of the water per second.

And 6·5×·75×2×5·1=49·725 cubic feet discharged in the same time.

1089.—*Explain by an example the motion of water in pipes.*

Let a vessel be kept constantly full of water up to the water line. In two horizontal places lower than the water-line, are made orifices, through which the water will pass up vertical nearly to the water-line. Omitting the resistance of air, the jet should theoretically reach the water-line; practically it reaches 0·967. It is evident that the velocity of the jet through the orifices must be the velocity due to a body falling from the height, according to the law of force of gravity.

1090.—*How many gallons of water will be discharged in five minutes, through an orifice of* 0·025 *square feet, applied at* 8 *feet under the level of the water?*

G=31·5 *a t mh*=31·5×0·025×5×60×8=189·00 gallons.

Where:—h=head, or height of water over the orifice,
t=operating time in seconds,
a=area of the orifice in square feet,
m=the coefficient for contraction,
G=gallons of 277 cubic inches discharged in the time,
V=velocity through the orifice in feet per second.

1091.—*What are the effects produced by pressure of water in its natural state?*

The pressure of water in a vessel, caused by its own gravity, increases in proportion to the depth below the surface. The sides of cisterns, vessels, flood-gates, and sluices sustain a pressure equal to the product of the area multiplied by half the depth of the fluid and by its gravity, in equal terms of unity.

The pressure of water on a horizontal surface, say the bottom of a cistern, is equivalent to the weight of the superincumbent column of water, and the intensity of the pressure is independent of the form of the vessel.

1092.—*Required the pressure of water on the sides of a rectangular cistern* 18 *feet in length,* 13 *feet in width, and* 9 *feet in depth.*

The terms of measurement or unity are in feet; 1 cubic foot of water = 62·5 lbs.; hence 18 × 9 × 2 × 13 × 9 × 2 = 75,816 × 4·5 × 62·5 = 21,885,750 lbs = pressure on the sides.

[The weight of water or other fluid is as the quantity, but the pressure exerted is as the vertical height; hence as fluids press equally in every direction, any vessel containing a fluid sustains a pressure equal to as many times the weight of the column or greatest height of that fluid as the area of the vessel is to the sectional area of the column. The pressure exerted upon the water by the ram of the force-pump is transmitted by means of a pipe to the base of the ram of the press, and as the pressure of fluids is equal in all directions, the total force acting on each ram will be in proportion to their areas. The ram is made water-tight by a leather collar, inserted in a groove at the top of the press cylinder. The water-presses inside the leather-collar causing it to open and press hard against the ram. When the pressure is taken off, the leather-collar closes, and permits the ram to fall down freely. The ram of the press acts with a force equal to the number of times the area of the end of the ram exceeds the area of the end of the pump-ram.]

1093.—*How may the buoyancy or upward force with which water presses on immersed body be ascertained?*

When a body is partly or wholly immersed in water or other fluid, the vertical pressure of the fluid tends to raise thebody with a force equal to the weight of the fluid displaced; hence the weight of any displaced quantity of a fluid by a buoyant body equals the weight of that body.

1094.—*By what rule is the velocity of discharge regulated?*

In the discharge of water by a rectangular aperture in the side of a reservoir and extending to the surface, the velocity varies as the square root of the height: and the quantity discharged per second equals ⅔rds of the velocity due to the mean height, allowing for the contraction of the fluid according to the form of the opening, which renders the co-efficient in this case equal to 5·1.

1095.—*Required the velocity of water issuing through an orifice under a head* 11 *feet from the surface.*

$\sqrt{11} = 3{\cdot}3166 \times 8{\cdot}1 = 26{\cdot}864$ feet, velocity per second.

1096.—*By what rule may we find the velocity of water issuing through a circular orifice at any given depth from the surface?*

Multiply the square root of the height or depth to the centre of the orifice by 8·1, and the product is the velocity of the issuing fluid in feet per second.

1097.—*What law regulates the flow of water through orifices?*

Water in flowing through an aperture under any given head, is governed by the same law of gravity as that of a solid body *in* *vacuo* descending through the same space; but as friction is created by the motion of two hard bodies in contact, so is friction also created by the action of the water in passing through an aperture; hence an aperture twice the width of another will discharge more than a double quantity, because the area advances in a much greater ratio to that of the resistance. Thus, suppose an opening of 4 square feet be required in a circular form its diameter would be about 2 feet 3 inches, and its circumference, or cause of friction, 7 feet; in a square form, 2 feet by 2 feet, and the amount of its sides 8 feet; but in a rectangular form, 4 feet in length and 1 in breadth, the cause of resistance is increased to 10 feet; thus showing that the circular form is that which should be adopted in preference to any other for the conduction of water where practicability will admit.

1098.—*What must be the thickness of sheet iron whereby to form a rectangular vessel 5 feet in length, 2 in width, and $1\frac{1}{4}$ in depth, that will just sink 3 inches in common water; laps, seams, and rivets not being taken into account?*

5 ft. or 60 in. × 15 = 900 × 2 = 1800 in. or sum of the sides.
„ 60 in. × 15 = 900 „ bottom.
2 ft. or 24 in. × 15 = 360 × 2 = 720 „ ends.

Total... 3420

And 3420 × ·281 = 961·02, the divisor,

Then 60 in. × 15 × 3 × ·03617 = 97·659 lbs. of water to displace. Hence 156·254 ÷ 1112·7 = ·14 in., thickness required.

1099.—*How may we calculate the theoretical velocity due to different heads of water?*

By the following formula in which V = theoretical velocity *in feet per second.*
v = theoretical velocity in feet per minute.
H = head of water in feet.

$$V = 8{\cdot}025\sqrt{H}. \quad v = 482\sqrt{H}.$$

1100.—*Apply the foregoing formula to a case in which there is a head of 10 feet.*

$$\begin{array}{r} 8{\cdot}025 = \sqrt{2g} \\ 3{\cdot}162 \\ \hline 25{\cdot}375 \end{array}$$

H = 10 feet head.
$\sqrt{H} = \sqrt{10} = 3{\cdot}162$

1101.—*By what formula is the pressure on the sides of vessels obtained?*

The side of any vessel sustains a pressure equal to its area multiplied by half the depth of the fluid, and the whole pressure upon the bottom and against the sides of a vessel is equal to three times the weight of the fluid.

1102.—*What is the pressure on the bottom of a conical, pyramidal, or cylindrical vessel containing fluids?*

The pressure is equal to the area of the bottom multiplied by the depth of the fluid.

1103—*By what formula may we find the weight of a cubic foot of any solid or liquid?*

Multiply the specific gravity of the body by 62·32, and the result obtained will be the weight of a cubic foot of the body in pounds avoirdupois.

1104.—*What is the pressure of a foot of water at 52·3 Fahr.?*

62·4 lbs on a square foot (the atmospheric or barometric pressure is not, as a rule, taken into consideration).

1105.—*Of what is a head of water constituted?*

It is made up of a *head of pressure,* and a *head of elevation.*

1106.—*What is the head of pressure?*

The head of pressure is equal to the intensity of the pressure exerted by the particles expressed in feet of water.

1107.—*What is head of elevation?*

It is equal to the actual height of the particle above the zone fixed or the "datum level."

1108.—*What is the rule for finding the pressure of fluid on the bottom of its containing vessel?*

Multiply area of base by height of fluid in feet and the product by the weight of a cubic foot of the fluid.

1109.—*What is meant by head of pressure?*

The intensity of pressure in feet of water.

1110.—*What is the absolute head of particles of water under pressure consist of?*

The head due to pressure and the head due to elevation.

1111.—*What is the ratio of the head of fresh to head of sea water?*

As 1: 1·026.

1112.—*In what way is the discharge of water expressed?*

In cubic feet per second.

1113.—*How is the mean velocity of flowing liquids measured?*

By dividing the discharge by the cross section.

1114.—*How is water pressure convertible into motion?*

The force of gravity in the form of weight is convertible into pressure, and pressure into motion; and that motion may be converted into pressure, and pressure be equivalent to weight.

Motion we are accustomed to measure by its rate, which we term its *velocity*; that is, the number of units of space passed over by the moving body in a unit of time, as, so many feet per second.

1115.—*How is the flow of water established?*

All forces tending to destroy equilibrium among the particles of a body of water tend to produce motion in that body.

1116.—*What is the action of gravity upon individual molecules?*

All natural flow of water is due to the force of gravity, acting upon and generating motion in its individual molecules. If in the side of a vessel filled with water there be made an orifice; if one end of a level pipe filled with water be lowered; or if a channel filled with water have its water released at one end, then equilibrium among the particles of the water will be destroyed, and motion of the water will ensue. Gravity is the force producing motion in either case, and it acts upon each individual molecule as it acts upon a solid body, free to move or devoid of friction.

1117.—*What is the pressure upon a unit of surface of water?*

Since one cubic foot of water, measuring 144 square inches on its base and 12 inches in height weighs 62·425 pounds, there must be a pressure exerted by its full bottom area of 62·425 pounds, and by each square inch of its bottom area of $\left(\frac{62{\cdot}425\text{ lbs.}}{144\text{ sq. in.}}\right) = 0{\cdot}433472$ pounds for each foot of vertical depth of the water.

In ordinary engineering calculations 62·5 pounds is taken as the weight of one cubic foot of water, and 0·434 pounds as the resulting pressure per square inch for each vertical foot of depth below the surface of the water. These weights are used in the computation of tables, and give closely approximate results, slightly in excess of the true weights.

1118.—*Is the pressure of water proportional to depth?*

The pressure of a fluid at any point on an immersed surface, is in proportion to the vertical depth of that point below the surface of the fluid; but not in proportion to variable breadths of the fluid.

1119.—*What is meant by individual molecular reactions in water?*

Any particle of fluid that receives a pressure re-acts with a force equal to the pressure, if its motion is resisted upon the opposite side. [Any point of a fixed surface pressed by a particle of water re-acts upon the particle with a force equal to the pressure of the particle.]

1120.—*Is the equilibrium in a volume of water destroyed by an orifice?*

If an orifice is made at the bottom of the side of a vessel containing water, then the particles at that point will be relieved of the re-action of the point, or of its support, equilibrium will be destroyed, and motion will ensue, and all the particles throughout will begin to move toward the orifice, though not with equal velocities.

1121.—*What is meant by the frictionless movement of molecules of water?*

The molecules of water move over and pass each other with such remarkable ease that they have usually been considered as devoid of friction.

1122.—*What is meant by acceleration of motion?*

The force of gravity perpetually gives new impulse to a falling body and accelerates its motion, if unresisted, in regular mathematical proportion.

1123.—*What is meant by transmission of pressure to a distance?*

The effect of pressure on a fluid is transmitted through its particles to any distance, however indefinitely great, to the limit of its volume.

Required the direction and magnitude of the pressure against a flat circular valve inclined to the horizon at an angle of 45°, and employed to retain fresh water in a reservoir; the centre of the valve is sixteen feet below the surface of the water, and the diameter of the valve one feet.

The direction of the pressure is at right angles to the valve.

The area of valve $= 12 \times 12 = 144 \times 7854 = 113{\cdot}06$.

The pressure of water per square inch at 16 feet is $\cdot 4332 \times 16 = 6{\cdot}9312$ lbs., therefore the pressure on the valve is $6{\cdot}9312 \times 113{\cdot}06 = 783{\cdot}849$ lbs., the total pressure on the valve.

1 cubic inch of water $= \cdot 0361$ lbs., $\therefore \cdot 0361 \times 12 = \cdot 4332$ lbs.

1124.—*How does the pressure of water in a vessel differ from its weight?*

The weight is according to the quantity, but the pressure is according to the perpendicular height.

[N.B.—The pressure against the side of a vessel increases in proportion to the square of the depth, but the velocity of a spouting pipe increases only as the square *root* of the depth.]

1125.—*What is necessary in a fluid particle in order for it to acquire velocity from a state of rest to an increase of velocity ?*

It must pass from a place of *greater total head* to a place of *less total head.*

1126.—*In hydraulics in what term is it consistent to express the intensity of pressure of water ?*

In *feet of water*, that is, in terms of the intensity of the pressure of a column of water one foot high upon its base as a unit.

1127.—*What other term is used for pressure so expressed ?*

A " head of pressure".

1128.—*What unit of time is employed in mechanics and hydraulics and in calculations on sewage and water works ?* .

Of different units of time the *second* is the most convenient in mechanical calculations; the *minute* is the customary unit in stating the discharge of streams; the *hour*, the day, and longer periods are used in calculations as to drainage and water-supply.

1129.—*What rule may be stated with regard to the velocity of fluids passing through an orifice ?*

The velocity at its passage through an orifice in the side of a reservoir, is the same as a heavy body would acquire in falling freely from the height comprised between the level of the fluid surface in the reservoir and the centre of that orifice.

1130.—*What formula is based on this ?*

The formula $V = \sqrt{2\,g\,H}$ where V = velocity of issue, and H = height of head of water in reserve, and g = gravity.

1131.—*What is meant by motion of the individual particles ?*

If an aperture is made in the bottom or side of a tank filled with water, the particles of water will move from all portions of the body toward the opening, and each particle flowing out will arrive at the aperture with a velocity, dependent upon the pressure or head of water upon it, and upon its initial position.

1132.—*What quantities of fluid are discharged in certain heads and apertures ; or what rules are observed in estimating the discharge from apertures under certain conditions of pressure ?*

1. The quantities of a fluid discharged in equal times by the same apertures, from the same head, are nearly as the areas of the apertures.

2. The quantities of a fluid discharged in equal times by the same apertures, under different heads, are nearly the square roots

of the corresponding heights of the fluid, above the surface of the apertures.

3. The discharge of fluid through a cylindrical horizontal tube, the diameter and length of which are equal to one another, is the same as through a simple aperture.

4. If the horizontal tube is of greater length than the diameter, the discharge of fluid is much increased, and may be increased with advantage up to a length of tube four times the diameter of the aperture.

1133.—*To what horizontal distance will a fluid spout from a horizontal pipe in any part of an upright vessel below the surface of the fluid?*

To a distance equal to twice the length of a perpendicular to the side of the vessel, drawn from the mouth of the pipe, to a semicircle described upon the altitude of the vessel.

1134.—*What is a pump?*

A pump is a machine for applying force to a fluid, either for the purpose of causing it to ascend from a lower to a higher level, or to make it flow against an opposing force other than gravity acting upon that portion of the fluid to be put in motion. This definition divides pumps into two great primary classes, which may be subdivided into several secondary classes, according to the special use to which the pumps are applied. Thus arranged, the subject appears as follows:—First division, pumps for drawing mines, pumps for surface drawing, pumps for irrigation, pumps for water-supply, pumps for raising particular liquids, contractors' pumps, pumps for emptying docks, bilge-pumps; second division, pumps for supply in hydraulic machinery, feed-pumps, and air-pumps.

1135.—*What consequences follow upon this principle?*

That a surface of equal pressure in a still fluid mass is everywhere perpendicular to the gravity that is longitudinal throughout. The pressure at all points at the same level is of equal intensity.

II. The intensity of the pressure at the lower of the two points in a still fluid mass is greater than the intensity at the higher point by an amount equal in weight to a column of the fluid whose height is the difference of elevation of the points, and base a unit of area.

III. The pressure of a liquid in a floating or immersed body is equal to the weight of the volume of water displaced by that body; and the resultant of that pressure acts vertically upwards through the centre of gravity of that volume, when the centre of gravity is called the centre of buoyancy.

IV. The pressure of a liquid against a plane surface immersed in it is perpendicular to that surface in direction, its magnitude is equal to the weight of a volume of the liquid, found by multiplying the area of the surface by the depth to which its centre of gravity is immersed.

V. The centre of pressure on such a surface if the surface is horizontal coincides with its centre of gravity if its surface is vertical, or sloping the centre of pressure is always below the centre of gravity of the surface and is found by considering that the pressure is an uniformly varying stress whose intensity at a given point varies as the distance of that point from the line where the given plane surface (produced if necessary) intersect the upper surface of the liquid.

1136.—*There is delivered from a coal pit 160 tons of water in twenty-four hours, but it is grossly polluted with solid matter; what measures would you suggest for its clarification, that a volume of twenty thousand gallons per day would be available for human use?*

The filtration process would be the best system to adopt. One ton water measures 224 gallons, 160 × 224=35840 gallons. To reduce gallons to cubic feet, divide by 6¼, or for greater accuracy, by 6·23. The cubic feet are therefore 5752·8. A reservoir 29 feet × 20 feet × 10 feet deep would hold this quantity after filtration. It should be carried to point of distribution in cast iron pipes under pressure. Service reservoirs should contain three days' supply. Thirty gallons per head per day is considered the average consumption in manufacturing towns. The reservoir should be a little larger than dimensions given.

1137.—*What is the pressure of a fluid at any part of an uncovered surface?*

The pressure of a fluid at any part of an uncovered surface is in proportion to the vertical depth of that point below the surface of the fluid but not in proportion to variable breadths of the fluid.

1138.—*By what formula may we calculate the time employed in filling and emptying a reservoir when the supply and consumption are going on simultaneously?*

Q = supply of water to reservoir in cubic feet per minute.
q = consumption of water from reservoir in cubic feet per minute.
c = contents of reservoir in cubic feet.
T = time required for filling reservoir in minutes.
t = time required for emptying reservoir in minutes.

$$T = \frac{c}{Q-q} \qquad t = \frac{c}{q-Q}$$

1139.—*How may we compute the pressure of a fluid down a vertical, inclined, curved, or any surface?*

Multiply the area of the surface by the height of the centre of gravity of the fluid in feet, and the product by the weight of a cubic foot of the fluid.

1140.—*Give the pressure on a sloping side of a pond of fresh water 10 feet square, the depth being 8 feet.*

Centre of gravity, 8÷2 = 4.
When $(10)^2 \times 4 = 400 \times 62{\cdot}5 = 25{,}000$ lbs.

1141.—*Required the direction and magnitude of pressure against a flat circular valve inclined to the horizon at an angle of 43° and employed to retain fresh water in a reservoir; the centre of the valve is sixteen feet below the surface of the water, and the diameter of the valve one foot.*

The direction of the pressure is at right angles to the valve.
The area of valve $= 12 \times 12 = 144 \times {\cdot}7854 = 113{\cdot}09$.

Pressure of water per square inch at 16 feet is $\cdot4332 \times 16 = 6{\cdot}9312$ lbs.

Therefore, the pressure on the valve is $6{\cdot}9312 \times 113{\cdot}09 = 783{\cdot}849$ lbs., the total pressure on the valve.

One cubic inch of water $= \cdot0361$ lbs. $\therefore \cdot0361 \times 12 = \cdot4332$ lbs.
Area of valve $= (D)^2 \times \cdot7854$. D = diameter.

1142.—*Under what condition of water is it taken as a standard of comparison between measures of capacity and weight?*

All comparisons between measures of capacity and those of weight are made with distilled water at a maximum density, at a specific gravity of 1 (unity); but in commercial measure, the vessel at a temperature of 62° Fahr.

1143.—*What is the main property of a fluid as opposed to a solid?*

It does not tend to preserve a definite shape.

1144.—*What principle is based upon this property?*

That in a perfect fluid, when still, the pressure exerted at a given point is normal to the surface as when it acts, and of equal intensity for all positions of that surface. [Upon this principle is founded the whole science of Hydrostatics.]

1145.—*What is meant by the intensity of pressure of fluid?*

In uniform pressure over an area, the total amount of pressure divided by the area.

1146.—*What is the pressure of water in a conical vessel?*

The pressure of the fluid in any conical vessel is found by multiplying the base by the whole perpendicular height; therefore the pressure will be equal to three times its weight.

[N.B.—A fluid presses in proportion to its perpendicular height and the base of the vessel containing it without any regard to the quantity.]

1147.—*What is the density of air in relation to water?*

As 1 : 773.

1148.—*What is the ratio of pressure on the sides of three vessels when the depths are as* 1, 2, 3, *to one another?*

Of three vessels whose depths are as 1, 2, and 3, the pressure against the side of the second will be four times greater than that against the first, and the pressure against the side of the third will be nine times greater than that against the first.

1149.—*What is the pressure on the side of a cubical vessel containing water?*

In any cubical vessel the pressure against any one side is equal to half the pressure upon the bottom, and, of course, the pressure upon the four sides is equal to twice the pressure upon the bottom.

1150.—*What is the "hydrostatic paradox"?*

"That any quantity of water, however small, may be made to balance and support any quantity, however large."

1151.—*What is absolute motion?*

It is the motion that bodies have independently of each other and only with regard to the parts of space.

1152.—*What is meant by relative motion?*

It is the degree and direction of the motion of any body, when compared with that of another.

1153.—*At what temperature does water attain its maximum density?*

At 39° 2 Fahr. or 4° Cent.

1154.—*What is the pressure against the whole side of a cubical vessel containing water?*

The pressure in this case must vary as the square of the depth of the vessel. [N.B.—The lateral or side pressure of fluids is equal to the perpendicular pressure.]

1155.—*How many cubic feet of water will be raised in one hour from a mine* 200 *feet deep, if the rate of pumping be* 15 *horse power?*

2376 nearly. [One horse power is equal to 550 foot pounds per second, and is nearly equivalent to 8·8 cubic feet of water lifted one foot high per second. A cubic foot of water=62·5 lbs. Foot lb.= work done against gravity in lifting a pound weight through a height of one foot.]

1156.—*A bottle filled with water weighs* 212 *grammes. Fifty grammes of filing are thrown in, and the water which* *flows over is removed, still leaving the bottle just filled. The bottle then weighs 254 grammes. What is the density of the filings?*

The density of the filings is 6·25.

1157.—*A hole is made in the side of a cistern containing water: what is the velocity with which the water is ejected?*

The velocity will be as the square root of the distance of the hole below the surface.

1158.—*How much water will a body specifically lighter than water displace when floating on its surface?*

A body specifically lighter than water will sink in it till so much of it is below the surface, that a bulk of water equal to the bulk of the parts of the body which is below the surface is of a weight equal to the weight of the whole body.

1159.—*How and to what distance is the pressure on a fluid transmitted?*

The effect of pressure is transmitted through its particles to any distance, however indefinitely great, to the limit of its volume.

1160.—*(a) What is the immediate cause of fluid motion, and (b) what are usually the secondary causes?*

(*a*) Gravity.

(*b*) The other accelerating forces are the extent of the mean radius or wetted perimeter, and the shape of the channel.

1161.—*Besides that loss of head from friction what other causes produce loss of head?*

There is frequently loss due to change of direction, caused by bends and angles in the pipes. When the bends are of large radius and are not numerous, their influence may be neglected, but angles and lends of a small radius occasion a considerable loss.

1162.—*What are the principal results required?*

The results principally required are the flood or maximum the catchment area; its mean discharge throughout the year, and discharge, in cubic feet per second of the river or stream, draining its minimum discharge in seasons of extreme drought, as well as in its ordinary low stage, dividing each of these by the catchment area, similar results per unit of catchment are obtained, to obtain the depth in feet of rainfall run off under each of those conditions. The relation between these quantities and the probable or approximate downpour over the catchment area can then be compared with those known to exist in other corresponding cases and a valuable check on these important results thus obtained.

1163.—*What are the best known formulæ for this calculation?*

The three best known formulæ for this purpose are:—

$$(1)\ Q = K_1\ \ 27\ (K)\tfrac{1}{2}$$
$$(2)\ Q = K_2\ \ 100\ (K)\tfrac{3}{4}$$
$$(3)\ Q = K_3\ \ 1300\ K\ (L)\tfrac{2}{3}.$$

In all these K is the catchment in square statute miles, Q the flood discharge in cubic feet per second, in the third L is the length of the main river or stream under consideration, in statute miles; while the co-efficient K_1, K_2, K_3, are the local drainage co-efficients suitable to each formula respectively.

1164.—*What is the disadvantage and advantage of formula* (1)*?*

Formula (1) requires a very wide range of valves of K_1, and is hence inconvenient, though simple in form.

1165.—*What are the uses of formula* (2)*?*

Formula (2) is preferable; it is a modification of Colonel Dickens' formula, $Q = 825\ (K)\tfrac{3}{4}$, suited to Bengal proper and Bahar, though it afterwards appeared that formula (2) with co-efficient near to $K = 8{\cdot}25$ was suited to large tracts of Indian plains having an annual rainfall of from 24 to 50 inches

1166.—*In assessing a water-tax what are the several points to be taken into consideration?*

In the assessment of a water-tax there are several points to be considered: (1), the original cost of construction of the work; (2), the means by which the money was furnished; (3) if by loan, the period over which the loan is extended, together with its interest and compound interest; (4), the annual expenses in the maintenance of the water works; (5), the actual population, and (6), the proportion of wealthy to pauper people, *i.e.*, the number by whom house-connections are likely to be made. In an entirely pauper population, or one, say, of a large agricultural village, the cost of maintenance of a constant water-supply system, either with or without the use of machinery for pumping, could not be met by rates, and loss would be inevitable; but where, as is the case in most towns of India, a part of the community is more or less wealthy, there is every facility for carrying out any method of supply that may be deemed expedient.

1167.—*How may we guard against the accidental failure of the ball-valve or cock?*

By using some kind of overflow pipe and since the water always enters under considerable pressure, it must, in order that it may discharge the same quantity in the same time, be very much larger than the supply-pipe. On no account whatever should it be carried into soil-pipe, waste-pipe, rain-water-pipe, or any pipe having any communication with the drains ; the interposition of a syphon bend in such cases is utterly useless, since as the ball-valve may get out of order the trap will always be dry. Overflow pipes of this old and objectionable kind are now happily prohibited by the Water Companies, not indeed on sanitary considerations, but because it was found to be a common practice of householders to tie up the ball-valve and allow the water to run to waste, with the object of flushing the house drains. The law now requires the overflow pipe to discharge itself in the open air, in some conspicuous situation where it can be seen from the street, or at least such that the householder must in self-defence have the ball-valve repaired without delay. They are then called warning pipes.

1168.—*What are the two kinds of taps in common use ?*

(*a*) The plug tap, which is like the tap of an ordinary gas jet ;
(*b*) The screw-down tap.

1169.—*What are their respective advantages and disadvantages ?*

The plug tap shuts off the water by a half turn, is therefore rapid in its action and for the intermittent system very good, as it is also in cistern pipes. It is not desirable in the constant system where the pressure is high; for this purpose screw-down taps are needed: screw taps save the water pipes from shock in the high pressure system : if a plug tap be used in these cases, the sudden shock to the pipes is very great as the flow of water is checked so suddenly.

1170.—*What are the best form of taps for houses supplied on the constant system ?*

The screw-down tap.

1171.—*Where should it be placed ?*

Where the pipe enters the house

1172.—*Who should have charge of this tap ?*

The tenant [with the tap in his possession]. The tenant may turn off the water should there be a burst in the pipe, or he can empty the pipes in frosty weather; screw-down taps have the advantage of stopping the water gradually without any concussion. It would appear also that notwithstanding the tendency not to shut these taps off completely, there is actually less waste involved in their use than with either of the other kinds. Hence this description of tap is the one specified as permissible in the "Regulations." Another advantage possessed by this tap is that it is easily repaired, and that frequently without the necessity for employing skilled labour.

1173.—*Name a good form of screw-down cock ?*

The various descriptions of screw-down cocks have each their advocates, but the one most generally in use is the high pressure loose valve tap. The working screw of the best description is contained in a separate top piece which screws into the body of the tap. The whole of the parts requiring renewal are connected with this top piece, which being screwed to a standard gauge, may in a few minutes be removed, and a new one substituted. The valve being loose causes the leather washer to be as durable as possible; the water however, in some cases, seems to affect its durability much more than in others, and when carelessly made fittings are permitted, washers last but a short time. A double-action bib-cock, designed to allow of its being repaired without turning off the water, may also be used. This is effected by having two valves, the upper of which acts in precisely the same manner; when however it is necessary to remove this valve for any purpose, a second valve is forced upwards into the valve seating, thus stopping for the time being the flow of water through the cock.

Where are bill-cocks chiefly used?

The plug-cock is, as a rule, only used in towns where an intermittent supply exists, and is nearly in all cases prohibited where there is a constant service. The plug-cock, although rather cheaper in first cost than the screw-down cock, is much the inferior one to use. It is liable to cause rupture of the pipes by concussion, and consequent leakage from the suddenness with which it stops the flow of water, and being expensive to keep in repair ultimately becomes the more costly article of the two. There are many varieties of bill-cock from the plug-cock to the screw-down with double-valve.

Ball-cocks or taps are so varied as bill taps, but those mostly in use for high pressure are the equilibrium taps of Messrs. Lambert and Son, Fig. 299, and Messrs. Guest and Chrimes; and the loose valve ball-cock of the latter firm. Fig. 250 is a section of Stone's patent sliding socket ball-valves. The length of the lever and size of the ball should be specified, being proportioned according to the pressure. Two or three inches space should be allowed between the highest water level and the outlet of the waste pipe, and cisterns should be so fixed that the ball-cock can be easily examined or repaired.

Waste Preventers.—There are several kinds of waste preventers in use. They are generally designed on the principle of arresting the flow of water after a limited quantity has passed, so that should the tap be carelessly left open, the water would nevertheless flow.

Self-closing taps of various descriptions have been tried at different places, but have generally been abandoned as they create concussion if the pressure is considerable. They were intended to reduce waste of water, but are often more likely to increase it, as some of the consumers, to avoid the inconvenience of holding the handle whilst water is being drawn, will prop or otherwise fasten it open and then carelessly leave it in that position.

1175.—*What are the uses of stop-taps?*

They are sometimes made to answer the purpose of a ferrule; and are at other times used separately, as a rule, either fixed on the foot path, or beside the house. The old plug-cock is still in use in some places, but is being superseded by the screw-down, loose valve stop-cock, which is much superior, as it avoids the concussion caused by closing the plug-cock; the loose valve also prevents the passage of foul air into the mains when they are emptied. It is also more durable, easier to repair, and if the double valve is used, the repairs can be done without shutting off the pressure in the mains.

1176.—*What is the use of a stop-ferrule?*

It forms a connection between the house service and the main, and is used for the purpose of cutting off the supply to a house when required for repairs, alterations and other purposes, without interfering with the flow of water in the main. It has a screwed end for attachment to the main, and a screwed or tinned end for connecting with the house services. A seating is made in the body of the ferrule, down upon which, when it is necessary to shut off the water, is screwed a loose valve similar to that in Fig. 297.

1177.—*What objection may be raised to the overflow pipe from a cistern opening on to the outer wall into the roof gutters?*

The pipe may become blocked up with ice in winter, which would render it useless, and the water would then overflow into the house.

CHAPTER IX.

METHODS OF WATER-SUPPLY—CONSTANT AND INTERMITTENT.

1178.—*What systems are employed in the distribution of water in public water-supplies?*

Two systems are in use—the *constant* and *intermittent* methods of supply.

1179.—*Describe what is meant by constant and what by intermittent water-supply.*

By 'constant' water-supply is meant the supply under pressure at all times of the day and night of water for domestic, trade, and other purposes. Or, in plain terms, the water mains are kept charged day and night, at such a uniform pressure that the water could, in case of fire, be forced over the highest buildings in the district or town.

By 'intermittent' water-supply is meant the supply of water at stated times, house-cisterns or other receptacles being necessary to store a day's supply. In the *intermittent* supply the householders, tenants or others requiring the water, can only obtain it at stated hours, or for a short period daily necessitating their storing it in tanks, house-cisterns, etc. In some cases the supply lasts for a few hours during the day but mostly it is limited to 20 or 30 minutes.

1180.—*Summarise the advantages of the constant service.*

(1) It requires no storage of water. Owing to the absence of cisterns, or improper receptacles, the risks connected with stagnant water, and with improper ending of overflow pipes, are obviated. There is no exposure to polluted air in the cisterns or to dust, mice, bird-droppings, insects, etc.

(2) The risk of suction into the pipes of external or soil contaminations is reduced to a minimum, since the pipes are never empty, with the mains and service-pipes always full and under pressure, the possibilities of the water becoming polluted are greatly reduced. Foul liquids and gases cannot easily find access to the interior of the mains through faulty joints, and pollution cannot be sucked in at the open end of the house service pipes if the pressure is always outwards.

(3) The pipes are less liable to rust; air, in the presence of a little moisture, causes rapid corrosion. Further there is an absence of gases which are either sucked in or generated within the pipes during the intervals of supply as occur in the intermittent system.

(4) There is an abundant supply of water in case of fire.

Of course, when there is a temporary stoppage of supply, as for repairs, some of the dangers incurred by an intermittent supply will arise even in the constant system.

There is no doubt that the constant system is the safer, especially for poor houses, as it leaves no loophole for inattention in the cleansing of cisterns. Only it requires that the constant system should really fulfil the conditions laid down for it, *viz.*, it should deliver sufficient water at all times, and not merely delude us with a phrase. [The only objectors to the constant service are the water companies. They urge that the fittings required for this system are expensive and liable to be stolen; and that, when through carelessness or accident, taps are left open or pipes burst, the waste of water is much greater than with a cistern supply. These objections have not been found to hold good where there is a well regulated and properly inspected constant supply; the increased waste with a constant supply, only occurs where it is adopted with the same fittings and pipes as were used for the intermittent supply. But where the best screw taps and fittings are provided and judicious regulations for preventing waste are enforced, the consumption of water is less than with an intermittent supply.

One valuable point in the constant system is that, in order to aid inspection and the detection of waste, the waste pipe is not allowed to open into any part of the drainage; but, under the name of a "warning pipe" is placed where the escape can be seen, and if in a house will put the owners or occupiers to inconvenience in consequence thereof.]

1181.—*How may waste be limited?*

To cheque waste in the pipes in the constant system, waste meters may be placed in various sections, and water works meter indicates position of leakage.

1182.—*Is the constant system always practicable?*

No; it may be necessary to adopt the intermittent system when the water is scarce. Thus, in some districts, the supply is only afforded for a certain number of hours in the day; and it becomes necessary for each household to store a sufficient supply for twenty-four hours, in elevated cisterns. The intermittent system, now becoming obsolete, is attended by many risks and disadvantages and is only defended on the grounds that it incurs somewhat less waste and that the substitution of constant service would entail considerable outlay in providing better fittings. The dangerous and filthy pollutions are thereby avoided.

1183.—*Are the advantages of the constant system always manifest?*

By no means; for in actual practice, in many cases, these advantages have been somewhat reduced by errors on the part of both consumers and water companies. Unless constant inspection is exerçised, and the taps and fittings in houses frequently supervised, there is great waste. This occurs especially in cases where an intermittent service has been changed to a constant service, and the old pipes and fittings have been retained. The company, to economise water, shut it off from the house-pipes, and then no water is obtainable, perhaps for many hours.

1184.—*What is done in order to limit the amount of domestic waste?*

In order to prevent undue waste water meters are sometimes applied to the service-pipe supplying a group of houses, and the landlord charged for the amount used, but as this plan induces the landlord to enforce a too rigid economy, it is not to be commended. The best water meters are capable of registering exactly all amounts exceeding a flow of one gallon per hour.

1185.—*Mention dangers to which water mains are liable when they are in proximity to sewers.*

If water mains and sewers are laid in the same trench, there is a possibility of foul matters, which have escaped into the soil from leaky sewers, being sucked into the water mains during intermissions in the service. In a similar manner, too, water mains may suck in from the surrounding soil coal-gas which has escaped from leaky gas pipes and mains. Such intermissions are the daily occurrences of an intermittent service, and are often unavoidable with a constant service when executing necessary repairs to the pipes. The water and sewerage systems should be kept as far apart as possible.

[With a constant service the mains are always charged in case of fire; with an intermittent service much valuable time is often lost in finding the turn-cock.]

1186.—*Name a special advantage of the intermittent system.*

The higher parts of the town do not run the risk of being deprived of water by the waste which takes place in the lower part.

1187.—*Name two special disadvantages of the constant system.*

Insufficient supply leaves the pipes empty at times, and foul air (it may be coal-gas or sewer air) is drawn in; and (2) if the pressure is low a ferrule is sometimes put in the pipe thus narrowing the diameter, so that the water runs in a very small stream.

In the intermittent system the water is cut off from the smaller mains, except for 20 minutes or half-an-hour, once or twice a day, or it is turned on for certain days of the week only, thus necessitating the storage of a supply in the house.

It is a common error to suppose that the constant service means an unlimited supply, and the intermittent a very much restricted one. In the former, the supply per head of population depends on the quantity that can be raised daily and the capacity of the storage reservoirs. As the water is always available, every precaution has to be taken in the constant system to guard against wilful waste, for if such waste were universal, the supply would soon terminate.

1188.—*What are the objections alleged against the constant system, and how far are these objections valid?*

The objections to the constant supply system are that it encourages waste and extravagance, and that no means can be taken to provide against these, (2) that the pipes and fittings are expensive, and (3) with weak or defective pipes or fittings, leakages and waste may occur. These objections are only valid when the taps and fittings used under the intermittent system are allowed to remain. When the constant system is adopted, only "screw-down taps" of the best description should be allowed; and to prevent waste from closets, a small cistern may be connected with each closet, containing two gallons or enough water for one "flush." It has also been suggested to put the service pipes in the poorer neighbourhood of a town in such a position on the landings that neglect shall cause such inconvenience as to enforce care.

[With the constant service occasionally pipes will have to be repaired; in that case the water must be turned off from mains or branches, and suction will then result just the same as with the intermittent. In both cases *defective mains or service pipes, although running borefull,* may draw in polluting matters. It has been proved experimentally that a fluid flowing through a tube with defective joints although the tube may be borefull and at some pressure, yet a vacuum may occur at the joints, and any gas or liquid in contact with the joints sucked; for instance, Mr. John Spear traced an epidemic of typhoid at Mountain Ash to the contamination of the water-main in the manner indicated. Another objection is the insufficient delivery when the supply is not abundant.]

1189.—*What points in connection with the constant system deserve special attention?*

The diameters of the pipes for constant service should be carefully adopted to their discharges and to the head of pressure; the drawing taps ought to be valve-cocks to open and shut with a screw, and the town should be efficiently provided with distributing basins so that an extra flow of water in one district would not interfere with the requisite supply of other parts. When the water is raised by pumping and there is no reservoir, the constant system is impracticable.

The late Dr. Parkes suggested that in the constant system a good screw stop-cock, available to the tenant, should be placed at the point of the entrance of the pipe into the house, so that the water may be turned off if pipes burst, or to allow the pipes to be empty, as during frost. Every precaution must be taken that impure water is not drawn into the pipes by a pipe being emptied and sucking up water from a distance.

1190.—*Discuss briefly and in general terms the subject of the intermittent and constant service of water.*

In almost all provincial towns, and in many parts of London, the water-supply is maintained constantly, save in times of exceptional drought. In some districts, however, the supply is only afforded for a certain number of hours in the day; and it becomes necessary for each household to store a sufficient supply for twenty-four hours, in elevated cisterns. The intermittent system, now becoming obsolete, is attended by many risks and disadvantages, and is only defended on the grounds that it incurs somewhat less waste, and that the substitution of constant service would entail considerable outlay in providing better fittings. On the other hand the cisterns, which must be large enough to meet the maximum (not the average) daily consumption, are costly, and are liable to be come foul; the water stored in them is stagnant, and absorbs impurities from the air coal-gas, sewer gases, or liquid filth are liable to be drawn into the mains and service pipes when empty; and, apart from this, the alternate contact with air and water tends to corrode the pipes, and favours the absorption of lead.

In the event of fire, a house or district under the intermittent system is at great disadvantage.

1191.—*What has been the chief objection raised by water companies to the constant system?*

It has been urged as an objection to the general adoption of the constant system of supply, that where an unlimited supply of water is at all times obtainable, there will be an undue use of water, a large portion of the water taken being allowed to run to waste. [Experience under the intermittent system of supply has furnished fallacious arguments for this contention.]

1192—*Has experience justified this statement?*

It has not: experience under the constant system has shown it to be an unfounded conclusion. It is not found, with a constant supply, that it is altogether impossible to limit the consumption—or rather consumption plus waste—to a reasonable amount.

1193.—*What was the cause of the antipathy that arose against the constant system?*

A prejudice was created against the constant system by the absurd regulations attempted to be introduced so as to prevent waste, such as the delivery of water through minutely constricted pipes so that the water would issue only in a dribble "throttling the supply."

1194.—*Can such regulations be carried out? What would be the result of giving effect to them?*

Such regulations are impracticable and dangerous in case of fire, and with proper supervision it is found that the substitution of a constant for an intermittent system has actually resulted in the saving of water. Indeed, in the present day, the relative values of the two systems can hardly be a matter of dispute; and no householder who has experienced the comfort and benefits of a constant supply, would willingly have a reversion to the intermittent system. Even for villages—and oftener for groups of villages—a constant supply is now-a-days frequently laid on, to the great comfort and advantages of rural populations.

1195.—*What is the true outcome of experience on the constant system?*

That with good regulations, vigilant inspection of cisterns, waste-pipes, and taps, waste is brought within reasonable limits, and the undue use of water may be limited in other directions. To large water-consumers the supply may be by meter; but it has not hitherto been found possible to supply water by meter in all cases.

1196.—*In changing a water service from intermittent to constant, what alterations in the fittings should be insisted upon?*

In changing from constant to intermittent supply the storage cisterns will become unnecessary, and may be removed; but the principal changes will be those to be made for the purpose of preventing waste. To this end "service boxes" will have to be furnished for all water-closets not already supplied with them; the taps must all be strong, serviceable articles, of the screw-down pattern, and it may be necessary, if the pressure be great, to require stronger service pipes than formerly.

1197.—*How far are the dangers connected with the constant and intermittent systems aggravated by prolonged frost?*

Dangers from faults in pipes occur after successive frosts from the expansion and eventual bursting of the pipes by the increase in bulk of the confined water in freezing. [During frosts, large areas supplied under a constant system may be wholly without water, both mains and pipes (laid at improper depths) being frozen.

Water was supplied from carts, received in all sorts of improvised receptacles, placed wherever there was room for them, thus introducing, in an aggravated degree, all the dangers of the intermittent system of storage.]

1198.—*Name some towns supplied on the constant system.*

London, Eastbourne, Birmingham, Wigan, etc.

1199.—*Name some towns supplied on the intermittent system.*

Oxford, Bath, Tunbridge Wells, etc.

1200.—*Why should the poorer classes be provided with water on the constant system?*

Because (1) there are no cisterns to be fouled and cleaned; (2) water is available at all times of the day; but it should be distributed to every house and every storey of the house.

1201.—*Can any compromise or intermediate method be introduced?*

Some engineers have proposed what may be called a compromise between the intermittent and constant systems. The objection to this plan is that cisterns are re-introduced, and their lessened size does not remove the objections to them.

1202.—*Enumerate the chief disadvantages to the constant supply.*

1. The fittings required are expensive.

2. If from accident or carelessness the pipes are left opened there is great waste. The same occurs if a pipe bursts.

[If well supervised and regulated these objections are not valid.]

1203.—*What are the disadvantages of the intermittent system?*

With an intermittent service of matter, during the intervals of supply, water is only obtainable from cisterns, water butts, etc. The objections against this system are that:—The cisterns required are expensive and liable to get out of order and become foul. The cistern is often composed of material which yields dangerous impurities to the water, such as lead, wood, etc., and as it is often placed in an inaccessible part of the house or is neglected, it becomes foul and remains so. (2) Their overflow pipes commonly communicate with the soil pipes or some other part of the drainage, instead of opening into the external air. (3) Putrid gases, from neighbouring stench pipes or other parts of the drainage system, are liable to be absorbed by the stagnant water in the cistern, and thus may arise diarrhœa, enteric fever, diphtheria, etc. (4) The chief objection to an intermittent supply is that during the intervals in which the water pipes are empty, foul air and liquids from the contiguous soil and drains are liable to be sucked through imperfect joints into the pipes. (5) In case of fire, the supply of water in the cistern is soon exhausted, and no more of it is obtainable until the turn-cock is found; thus there is often delay at the most important time. The importance of this evil is shown by the great reduction in insurance rates in Manchester, Liverpool, and other places, on the substitution of a constant for an intermittent service.

Another disadvantage of the intermittent service is that the capacity of the cistern is often utterly inadequate, especially in poor houses, for the wants of the people, who depend upon it as their only source of supply. So great is this deficiency of storage capacity in many parts of London, that the water companies erect stand-pipes in courts and alleys, which are connected with a main always under pressure.

This latter point has been disputed, as regards the pipes, on the ground that there is a greater strain on the pipes where the water is suddenly turned on and off with a common stop-cock, than where it is slowly turned on or off by the screw-down tap used with a constant service; but it must be remembered that with a constant service the water in the house pipes is under a much lighter pressure than where the pipes are connected with a cistern in the house.

In poor districts, the cisterns are often of a very inferior description, are badly situated, and are seldom inspected or cleaned out.

So many are the objections to the intermittent system that it is rapidly falling into disfavour and is being replaced by the constant. Almost all new public works are constructed for the constant system of supply.

1204.—*What has been proposed to overcome the disadvantage of small, or badly-made cisterns in poor districts?*

To meet the objection, it has been proposed to have one large tank for the supply of a group of houses, the tank to be under the immediate inspection of the water-works officials and to be filled daily, and the householders to be supplied through small pipes constantly charged.

1205.—*Enumerate briefly the disadvantages of the intermittent system.*

1. The cisterns required are expensive and liable to get out of order.
2. Their overflow pipes sometimes communicate with the soil pipe or some other part of the drainage system instead of opening into the external air.
3. Putrid gases from neighbouring stench pipes may be absorbed.
4. During the interval the waste pipes are empty, and foul air may be sucked in from contiguous soils and drains.
5. In case of fire the water is not to be had.

1206.—*How may the water be contaminated in the pipes by intermittent system?*

When the pipes and mains are empty of water, especially if the joints be badly fitted, or if there be holes in the pipes, foul air is sucked in and fills the pipes and mains, and the next time the water is turned on these gases are absorbed and carried to the houses; also if near leaky sewers, foul water may get into the water pipes through leaky joints or holes, and be carried into the cisterns the next time the water is turned on.

1207.—*Could this happen with the constant system?*

Not if the water is under high pressure and not flowing with too great velocity; but if the water flow rapidly past a hole or leaky joint, foul gases, foul fluids, and debris might be sucked in, or more probably forced in by the pressure of the surrounding atmosphere; the rapid passage of the water along the pipe rarefies the air in the hole in question. The risk of this, however, is far greater in the intermittent system.

1208.—*What are the disadvantages of the constant supply (a) to the consumer, and (b) to the water company?*

The objections to this system are only removable failures, there is no chance of contamination except in the pipes or reservoir. The disadvantages are:—

(*a*) *To consumer.*—There are none if there be "abundance" of water, as to Glasgow; but if it has to be economised it is often shut off, and the houses get none for hours, though this is usually done at night. Again, sometimes a throttle valve, ferrule, pin, or pea is put into the house pipe to reduce its diameter, and then if the pressure be small the water only "dribbles" into the house, and one must wait for a couple of hours or so before enough water can be got for an ordinary bath; or, again, a water meter is put on and the water charged accordingly, and this leads to sparing use and damage to health. All these points, of course, are meant to save the company's pocket, but tell against the consumer. It is best to have a constant service at high pressure and direct from the main—no cisterns, or storage tanks, or "pea" in the throat of the house pipe.

(*b*) *To the company.*—The "constant" system, it is said, is apt to lead to great waste of water from bad fittings, fraudulent abstraction of water, the fittings stolen and great waste occurs before the theft is discovered. All this can be remedied by effective control and proper appliances.

1209.—*Upon this point what has Sir* GEORGE BUCHANAN *shown?*

"That there is danger of in-suction if a perforation exists in a descending pipe, and especially at a point of constriction, even if the pipe is constantly full."

1210.—*What are the causes of waste in the "constant" system?*

1. Escape between the main and the house; this belongs to the water company.

2. Careless consumption or wilful abuse. To check this the company's officers must supervise the taps and pipes, or waste preventors may be introduced; the company has also power by Act of Parliament to enter houses and see that there is no waste, and can also repair fittings at the expense of the tenant.

3. Waste from improper apparatus and fittings. All fittings should be examined and stamped before they are sent out; and in some places only authorised plumbers are allowed to fix them up. If meters are used, do not charge for every drop, like gas, because the people will not use enough and fall into ill-health, sewers will become blocked, etc. Allow a certain quantity each day, say 25 gallons per head, and only charge above this amount.

1211.—*How may the waste in the constant system be prevented?*

By having good pipes, well jointed, good fittings to hydrants, screwed-down taps, and using Deacon's waste water meters over the supplied area.

1212.—*What objection is there to the use of small meters?*

The small meters sometimes used do not act well, and, in fact, they are said to allow the liquid to pass through them unregistered. The same cannot be said of large meters. Water companies, charging rates, appear to have an invincible repugnance to supplying water on any but a very large scale by meter. For towns the preponderance of opinion is undoubtedly in favour of the constant system as best securing economy of water, purity, palatability, coolness, and personal and domestic cleanliness.

1213.—*Mention a method of economising water supplied in the constant system.*

That a cistern large enough to hold a twenty-four hours' supply, be provided for each house and that the service pipes shall be of a diameter to deliver the required quantity during that time, and nothing more. Every cistern supplied in this way would become gradually emptied during the day time and would be refilled during the night, and this plan is open to the great objection attaching to the intermittent system, and does not sufficiently provide for emergencies. [In the constant service there is no interceptor between the supplier and the consumers. The actual amount of water consumed in the constant system has been calculated to be less than on the intermittent plan, but the waste is undoubtedly greater.]

1214.—*What is the essential difference between the intermittent and constant methods of supply?*

The essential difference between the two plans is that in the first case there is storage in the houses for from one to three days; while in the latter case there is either no storage, or it is only on a very small scale for two purposes, *viz.*, for water-closets and for the supply of kitchen boilers. It should, however, be understood that the constant supply has not always meant in practice an unlimited supply, nor has it been the case that the water in the house pipes was always in direct communication with the water in the reservoirs. On the contrary, the water to the houses has often been cut off, particularly in places where the supply was limited, and the fittings not good, and where there was great waste. [Water should be laid on to every house, and to each floor in the houses of the poorer classes. An insufficient supply leads to deficient washing of persons, clothes, houses, yards, streets and drains, and produces a lowered state of health among the population.]

1215.—*What is Prof.* FRANKLAND'S *opinion in regard to the constant and intermittent systems of supply?*

1. All storage of drinking water in houses is attended with the risk of pollution. Good water is spoiled, and bad water rendered

worse by the intermittent system of supply. All drinking water ought to be drawn direct from the main.

2. Under proper supervision, the waste of water is less on the constant than it is on the intermittent system of supply.

3. These and other advantages have led to the adoption of the constant system in a great majority of British towns.

1216.—*What is meant by "double supply"? What are its advantages and disadvantages?*

In view of the difficulty which sometimes exists, of obtaining from a single source a sufficiently abundant supply of good water to meet the wants of a large community, it has often been proposed to adopt a system of double supply, *i.e.*, to furnish water of two qualities. It is true that for many purposes, as for extinguishing fires and for sprinkling streets, a water would answer which would not be suitable for drinking, and such a supply might in many cases be easily procured, while to procure an abundance of water well suited for drinking would involve a large outlay. To the double system there is no objection, if the poorer water can be drawn only from street-hydrants, which are under municipal control, but it is not practicable to supply two sorts of water to private dwellings, with any security that the distinction between them will be regarded; no domestic, and indeed no average inhabitant, will fail to use for all purposes that water which is most handily obtained, unless, indeed, it be actually repulsive to the taste. In the case of large cities, it is seldom that a single source of sufficient size can be found, and it becomes a question to be settled by local considerations whether each portion of the supply shall be distributed to a different section of the city, or whether the water from all sources shall be united in a common reservoir or reservoirs, and distributed therefrom.

CHAPTER X.

SANITARY LAWS RELATING TO WATER AND WATER-SUPPLIES.

1217.—*What are the general powers and duties of an Urban Authority under Public Health Act, 1875, with regard to water-supply?*

They are given general powers for supplying district with water, *viz.*, to construct waterworks, dig wells, lease, hire, or purchase water works, and to contract to supply water; to carry mains within and without district; to supply water by measure; to supply water to adjoining district; to close polluted wells; to borrow money to carry out any of the above.

As general duties in this respect, they are to keep water works in good order and repair, and to supply pure and wholesome water; in some cases to require houses to be supplied with water; to supply water when required for public baths and for trading purposes; to provide fire plugs; to prosecute persons polluting the water. (P. H. A., 1875, secs. 51—55.) Local authority cannot supply water if there is a good supply from existing company to district. (Sec. 52, P. H. A., 1875).

Note.—Individuals may object if they are affected by the construction of water works. (Sec. 53, P. H. A., 1875.)

1218.—*What provision is made for the prevention of pollution of water-supplies, and what penalty attaches to persons apprehended for causing pollution?*

Section 70 of the Act which relates to this subject runs as follows:—"On the representation of any person to any local authority that within their district, the water in any well, tank or cistern, public or private, or supplied from any public pump, and used or likely to be used by man for drinking or domestic purposes, or for manufacturing drinks for the use of man, is so polluted as to be injurious to health, such authority may apply to a court of summary jurisdiction for an order to remedy the same; and thereupon such court shall summon the owner or occupier of the premises to which the well, tank or cistern belongs, if it be private, or in the case of a public well, tank, cistern or pump, any person alleged in the application to be interested in the same: and may either dismiss the application or may make an order directing the well, tank, cistern or pump, to be permanently or temporarily closed, or the water to be used for certain purposes only, or such other order as may seem to them to be requisite to prevent injury to the health of persons drinking the water."

The court may order the water to be analysed, and if the person on whom an order is made, fails to comply with the same, the court may, on the application of the local authority, authorise them to do whatever may be necessary in the execution of the order, and expenses may be recovered from the person on whom the order is made.

1219.—*What provisions are made for the inspection of water-supply by S.A.?*

Every rural S. A. must, through their officers or otherwise, provide for the periodical inspection of the water-supply of their district.

1220.—*What powers of entry are given in respect to inspection of water-supply in houses and premises?*

By section 7 the same powers of entry as are given by sections 102 and 103 of the P. H. A., 1875, regarding nuisances.

1221.—*What do sections* 51 *to* 61 *of the P. H. A.*, 1875, *deal with?*

Sections 51 to 61 deal with the power to provide water-supply and the restrictions thereon.

1222.—*What are the most important laws concerning water-supply contained in the P. H. A.,* 1875 *?*

Those dealt with in sections 51 to 67. Local Boards *may* supply, and in case of danger to health of inhabitants of a district for want of water or proper water, *shall* supply, water to their constituents; in case of their failure to do so Local Boards may be compelled to supply or may have a supply provided at their cost by a machinery to be set in motion by the Central Government. Local Boards may require, that houses without a proper supply of water, be supplied, and institute such a supply at the cost of the owners, and at an expenditure for the water supplied not exceeding two pence per week or a certain maximum, to be fixed by the Local Government Board. (Public Health Act, 1875, secs. 51 to 67.)

1223.—*What does section* 62 *of the P. H. A.,* 1875, *deal with?*

This section runs as follows:—

"Where on the report of the surveyor of a local authority it appears to such authority that any house within their district is without a proper supply of water, and that such a supply of water can be furnished thereto at a cost not exceeding the water rate authorised by any local Act in force within the district, or where there is not any local Act so in force at a cost not exceeding two pence a week, or at such other cost as the Local Government Board, may on the application of the local authority determine under all the circumstances of the case to be reasonable, the local authority shall give notice in writing to the owner, requiring him, within a time therein specified, to obtain such supply, and to do all such works as may be necessary for that purpose.

"If such notice is not complied with within the time specified, the local authority may, if they think fit, do such works and obtain such supply, and for that purpose may enter into any contract with any water company supplying water within their district. The water rates may be made and levied on the premises by the authority or company which furnishes the supply and may be recovered as if the owner or occupier of the premises had demanded a supply of water and were willing to pay water rates for the same, and any expenses incurred by the local authority in doing any such works, may be recovered in a summary manner from the owner of the premises, or may by order of the local authority be declared to be private improvement expenses."

1224.—*With what do sections* 68, 69 *and* 70 *deal?*

With the pollution of streams by gas washing or sewage; and section 70 with pollution of wells, tanks, etc. Sec. 70 runs as follows:—

"On the representation of any person, to a local authority, that within their district the water in any well, tank or cistern, public or private, or supplied from any public pumps, and used or likely to be used by man for drinking or domestic purposes, or for manufacturing drinks for the use of man, is so polluted as to be injurious to health, such authority may apply to a court of summary jurisdiction for an order to remedy the same; and thereupon such court shall summon the owner or occupier of the premises to which the well, tank or cistern belongs, if it be private, and in the case of a public well, tank, cistern or pump, any person alleged in the application to be interested in the same, and may either dismiss the application or may make an order directing the well, tank, cistern or pump to be permanently or temporarily closed, or the water to be used for certain purposes only, or such other order as may appear to them to be requisite to prevent injury to the health of persons drinking the water."

"The court may, if they see fit, cause the water complained of to be analysed at the cost of the local authority applying to them under this section."

"If the person on whom an order under this section is made fails to comply with the same, the court may, on the application of the local authority, authorise them to do whatever may be necessary in the execution of the order, and any expenses incurred by them may be recovered in a summary manner from the person on whom the order is made."

"Expenses incurred by any rural authority in the execution of this section, and not recovered by them as aforesaid, shall be special expenses."

1225.—*What is the definition of the word "stream" as given in the P. H. A.,* 1875*?*

The word "stream" is defined by section 20 as follows:—

"*Stream* includes the sea to such extent and tidal waters to such point, as may, after local inquiry and on sanitary grounds, be determined by the Local Government Board, by order published in the *London Gazette.* Save as aforesaid, it includes rivers, streams, canals, lakes, watercourses, other than watercourses, at the passing of this Act, mainly used as sewers, and emptying directly into the sea or tidal waters, which have not been determined to be streams within the meaning of this Act by such order as aforesaid."

1226.—*Is it the duty of Rural Authority to provide or require provision of sufficient water-supply, and what procedure is to be adopted for enforcing sufficient water-supply for such requirement?*

It is; the law upon this point is as follows:—It shall be the duty of every rural sanitary authority, regard being had to the provisions in this Act contained, to see that every occupied dwelling-house within the district has within a reasonable distance an available supply of wholesome water sufficient for the consumption and use for domestic purposes of the inmates of the house.

Where it appears to a rual sanitary authority, on the report of their inspector of nuisances, or their medical officer of health, that any occupied dwelling-house within their district has not such supply within a reasonable distance, and the authority are of opinion that such supply can be provided at a reasonable cost not exceeding a capital sum the interest on which at the rate of five per centum per annum would amount to twopence per week, or at such other cost not exceeding a capital sum the interest on which at the rate of five per centum per annum would amount to three pence per week, as the Local Government Board may, on the application of the local authority, determine under all the circumstances of the case to be reasonable, and that the expense of providing the supply ought to be paid by the owner or defrayed as private improvement expenses, proceedings may be taken as follows:—

(1) The authority may serve on the owner of the house a notice requiring him within a time specified in the notice and not exceeding six months from the date of the service thereof to provide such supply, and to do all such works as may be necessary for that purpose.

(2) If the expiration of the time so specified, the notice is not complied with, the authority may serve on the owner a second notice, informing him that if the requirements of the first notice are not complied with within one month from the date of the service of the second notice, the authority will themselves provide such supply, and that the expense of providing the supply will in that case be payable by the-owner or as a private improvement expense.

(3) If at the expiration of one month from the date of the service of the second notice, the requirements of the first notice are not complied with, the authority may, subject as in this Act is mentioned, themselves provide the supply, and for that purpose they may enter upon the premises and execute all such works as appear to them necessary for obtaining a supply of water for the houses, and for the purposes of such entry, sections 102 and 103 of the Public Health Act, 1875, shall apply until the works are completed, in the same manner as if an order of a court of summary jurisdiction had been made for the abatement of a nuisance on the premises and that order had not been complied with.

(4) Any expenses incurred by the authority in providing such supply and doing such works may, when the supply has been provided, be recovered in a summary manner

from the owner of the house, or may, at the option of the authority, be declared by their order, to be private improvement expenses.

(5) Where the owners of two or more houses have failed to comply with the requirements of the notices served on them under this section, and the authority might, under this Act, execute the necessary works for providing a water-supply for each house, the authority may, if it appears to them desirable and no greater expense would be occasioned thereby, execute works for the joint supply of water to those houses and apportion the expense as they deem just.

The authority may, on excuse being shown to their satisfaction why the requirements of a notice served by them under this section, should not be complied with, withdraw the notice or modify the requirements thereof.

Provided that nothing in this section contained shall be deemed to relieve the authority from the duty imposed upon them by the Public Health Act, 1875, of providing their district or any contributory place or part of a contributory place therein with a supply of water in cases where danger arises to the health of the inhabitants from the insufficiency or unwholesomeness of the existing supply, and a general scheme of supply is required, and such supply can be got at a reasonable cost. (Public Health (Water) Act, 1878, 41 and 42 Vict., ch. 25, sec. 3.)

1227.—*May the owner appeal against requirement to provide water-supply?*

In regard to this matter section 4 of the P. H. (W.) Act, 1878, states:—"Where an owner of a house has been required by the notice of a rural sanitary authority to provide a supply of water for his house, and objects to such requirement on any of the following grounds; (that is to say,)

(1) that the supply is not required; or

(2) that the time limited by the notice for providing the supply is insufficient; or

(3) that it is impracticable to provide the supply at a reasonable cost; or,

(4) that the authority ought themselves to provide a supply of water for the district or contributory place in which the house is situate, or to render the existing supply of water wholesome; or,

(5) that the whole or part of the expense of providing the supply, or of rendering the existing supply wholesome, ought to be a charge on the district or contributory place;

he may within twenty-one days after service on him of the second notice, address a memorial to the authority, stating his objections, and in that case it shall not be lawful for the authority to proceed with the execution of the works which they might otherwise execute under this Act until they have been authorised to execute the same by a court of summary jurisdiction or by the Local Government Board in manner hereinafter provided.

If the objections stated in the memorial do not include either the fourth or fifth of the above-mentioned grounds, the authority may apply to a court of summary jurisdiction for an order authorising them to proceed with the works, and thereupon the court shall summon the owner, and, if satisfied on hearing the case that the objections are not well founded, shall make an order authorising the authority to proceed with the works in the event of their not being executed by the owner within a time limited by the order.

If the objections stated in the memorial are or include the fourth and fifth of the above-mentioned grounds, or either of them, the authority shall forward a copy of the memorial to the Local Government Board, who may either cancel the requirement of the authority or confirm the same, with or without modifications.

If the Local Government Board confirm the requirement they shall issue an order authorising the authority, subject to such modifications, if any, as they prescribe, to execute the works in the event of such works not being executed by the owner within a time limited by the order.

Any such order may, if the Local Government Board think it equitable so to do, apportion the expense of providing the supply between the owner of the house and the authority of the district comprising the contributory place in which the house is situate, or between the owner and any other person or persons.

If the Local Government Board cancel the requirement on the ground that the authority ought themselves to provide a supply of water for the district or contributory place in which the house is situate, or to render the existing supply wholesome, the memorial shall be deemed to have been a complaint of default made to the Local Government Board against the authority under the 299th section of the Public Health Act, 1875."

1228.—*Do the powers of the P. H. (W.) Act of* 1878, *abrogate those of other Acts relating to water ?*

They do not; "all powers given by this Act. shall be deemed to be in addition to and not in derogation of any other powers conferred by Act of Parliament, law or custom."

1229.—*May one or two part-owners or both appeal against apportionment of expenses of water-supply ?*

He, or they may. "Where the expenses of providing a joint-supply of water for two or more houses are apportioned under this

Act by a rural sanitary authority among owners of the several houses, notices of such apportionment shall be forthwith given to each of such owners, and if any owner objects to the apportionment as unjust, he may, within twenty-one days after service on him of notice thereof, apply to a justice, and thereupon the justice may summon the authority and also the other owners, to show cause before a court of summary jurisdiction why the apportionment should not be varied, and the court may either dismiss the application or make such order varying the apportionment as to the court may appear reasonable." (P. H. (W.) A., 1878, section 5.)

1230.—*May houses in rural districts be erected or re-built without sufficient water-supply being provided?*

They may not. "It shall not be lawful in any rural district for the owner of any dwelling-house which may be erected after the date of the commencement of this Act, or of any dwelling-house which after that date may be pulled down to or below the ground floor and rebuilt, to occupy the same, or cause or permit the same to be occupied, unless and until he has obtained from the sanitary authority of the district a certificate that there is provided, within a reasonable distance of the house, such an available supply of wholesome water as may appear to such authority, on the report of their inspector of nuisances or of their medical officer of health to be sufficient for the consumption and use for domestic purposes of the inmates of the house.

If the sanitary authority refuse to grant such certificate, the owner may apply to a court of summary jurisdiction for an order authorising the occupation of the house notwithstanding the refusal of the certificate, and thereupon the court shall summon the authority, and if the court after hearing the case, is of opinion that the certificate ought to have been granted, the court may make an order authorising the occupation of the house.

Any owner who occupies a house, or causes or permits it to be occupied in contravention of this section, shall be liable on conviction by a court of summary jurisdiction to a penalty not exceeding ten pounds." (P. H. (W.) A., 1878, section 6.)

1231.—*What is the section of the P. H. (W.) Act of* 1878 *in regard to the periodical inspection of water-supply?*

Sec. 7, which runs as follows:—

"It shall be the duty of every rural sanitary authority from time to time to take such steps as may be necessary to ascertain the condition of the water-supply within their district, and the authority may pay all reasonable costs and expenses incurred by them for the purpose of taking such steps. The authority, or any of their officers, or any person duly authorised in writing for that purpose by the authority, if they or he have or has reasonable ground for believing that any occupied dwelling-house within the district is without a proper supply of wholesome water, sufficient for the consumption and use for domestic purposes of the inmates of such house, shall be admitted into the premises for which such supply is required or from which the water-supply may be derived for the purpose of ascertaining whether or not such house has such a supply within a reasonable distance; and for the purposes of any such admission sections 102 and 103 of the Public Health Act, 1875, shall apply in the same manner as if such admission were necessary for the purpose of examining as to the existence of any nuisance on the premises, and the person so authorised as aforesaid were an officer of the rural sanitary authority (section 7).

1232 —*What is the section of the P. H. (W.) Act*, 1878, *regarding the rating for water-supply by stand-pipes ?*

Sect. 9, which is as follows : —"Where a rural sanitary authority have provided a stand-pipe or stand-pipes for the supply of water to any portion of their district, they may recover water rates or water rents from the owner or occupier of every dwelling-house within two hundred feet of any such stand-pipe, in the same manner in all respects as if the supply had been given on the premises.

Provided that if any such dwelling-house has, within a reasonable distance, and from other sources, a supply of wholesome water sufficient for the consumption and use of the inmates of the house, no water rate or water rent shall be recoverable from the owner or occupier of the house unless and until the water supplied by the authority by means of such stand-pipes is used by inmates of the house."

1233.—*May the powers given to R. S. A. by the P. H. (W.) Act of* 1878, *be also invested in Urban Sanitary Authorities in certain cases ?*

They may ; for by sec. 11, "the Local Government Board may, if they think fit, by order invest any Urban Sanitary Authority with all or any of the powers and duties which are by this Act given to a rural sanitary authority and such investment may be made either unconditionally or subject to any conditions to be specified by the Board as to the time, portion of the district, or manner during at or in which the powers and duties are to be exercised.

1234.—*What is the meaning of the words "persons", "stream", "solid matter", "polluting", "sanitary authority", as given in the Rivers Pollution Prevention Act of* 1876 *?*

In this Act, if not inconsistent with the context, the above mentioned terms have the following meanings hereinafter respectively assigned to them, that is to say,

"*Persons*"—Includes any body of persons, whether corporate or incorporate :

"*Stream*"—Includes the sea to such extent, and tidal waters to such point, as may, after local inquiry and on sanitary grounds, be determined by the L. G. B., by order published in the London Gazette. Save as aforesaid it includes rivers, streams, canals, lakes, and water-courses, other than water-courses at the passing of this Act, mainly used as sewers and emptying directly into the sea, or tidal waters which have not been determined to be streams within the meaning of this Act by such order as aforesaid:

"*Solid matter*"—Shall not include particles of matter in suspension in the water:

"*Polluting*"—Shall not include innocuous discolorations:

"*Sanitary Authority*"—Means in the metropolis as defined by the Metropolis Management Act, 1855, any local authority acting in the execution of the Nuisance Removal Act for England, 1855, and the Acts amending the same; elsewhere in England, any U. or R. S. A., acting in the execution of the P. H. A., 1875.

1235.—*What is the prohibition as to putting solid matters into streams?*

This is dealt with in the Rivers Pollution Act, 1876, and the section regarding it runs as follows:—

"Every person who puts or causes to be put or to fall or knowingly permits to be put or to fall or to be carried into any stream, so as either single or in conbination with other similar (acts) of the same or any other person to interfere with its due flow, or to pollute its waters, the solid fluid of any manufactory, manufacturing process or quarry or any rubbish or cinders, or any other waste or any putrid solid matter, shall be deemed to have committed an offence against this Act.

In proving interference with the due flow of any stream or in proving the pollution of any stream, evidence may be given of repeated acts which together cause such interference or pollution, although each act taken by itself may not be sufficient for that purpose. (Section 2.)

1236.—*What is the prohibition as to drainage of sewers into stream?*

"Every person who causes to fall or flow or knowingly permits to fall or flow or to be carried into any stream any solid or liquid sewage matter, shall (subject as in this Act mentioned) be deemed to have committed an offence against this Act.

Where any sewage matter falls or flows or is carried into any stream along a channel used, constructed, or in process of construction at the date of the passing of this Act for the purpose of conveying such sewage matter, the person causing or knowingly permits the sewage matter so to fall or flow or to be carried shall not be deemed to have committed an offence against this Act, if he shows to the satisfaction of the court having cognizance of the case, that he is using the best practicable and available means to render harmless the sewage matter so falling or flowing or carried into the stream.

Where the Local Government Board are satisfied after local inquiry that further time ought to be granted to any sanitary authority, which at the date of passing of this Act is discharging sewage matter into any stream, or permitting it to be so discharged, by any such channel as aforesaid for the purpose of enabling such authority to adopt the best practicable and available means for rendering harmless such sewage matter, the Local Government Board may by order declare that this section shall not, so far as regards the discharge of sewage matter by such channel, be in operation until the expiration of a period to be limited in the order.

Any order made under this section may be from time to time renewed by the Local Government Board, subject to such conditions, if any, as they may see fit.

A person other than a sanitary authority shall not be guilty of an offence under this section in respect of the passing of sewage matter into a stream along a drain communicating with any sewer belonging to or under the control of any sanitary authority, provided he has the sanction of the sanitary authority for so doing." (Rivers Pollution Prevention Act, 1876, section 3.)

1237.—*What are the laws as to prohibition of drainage from manufactories into streams?*

" Every person who causes to fall or flow or knowingly permits to fall or flow or to be carried into any stream, any poisonous, noxious, or polluting liquid proceeding from any factory or manufacturing processes shall (subject as in this Act mentioned) be deemed to have committed an offence against this Act.

Where any such poisonous, noxious, or polluting liquid as aforesaid falls or flows or is carried into any stream along a channel used, constructed, or in process of construction at the date of the passing of this Act, or any new channel constructed in substitution thereof, and having its outfall at the same spot for the purpose of conveying such liquid, the person causing or knowingly permitting the poisonous, noxious, or polluting liquid so to fall or flow or to be carried shall not be deemed to have committed an offence against this Act if he shows to the satisfaction of the court having cognizance of the case that he is using the best practicable and reasonable available means to render harmless the poisonous, noxious, or polluting liquid so falling or flowing or carried into the stream." (R. P. P. Act, 1876, section 4.)

1238.—*What is the prohibition as to the drainage from mines into stream?*

" Every person who causes to fall or flow or knowingly permits to fall or flow or to be carried into any stream any solid matter from any mine in such quantities as to prejudicially interfere with its due flow, or any poisonous, noxious, or polluting solid or liquid matter proceeding from any mine, other than water in the same condition as that in which it has been drained or raised from such mine, shall be deemed to have committed an offence against this Act, unless in the case of poisonous, noxious, or polluting matter he shows to the satisfaction of the court having cognisance of the case that he is using the best practicable and reasonable available means to render harmless the poisonous, noxious, or polluting matter so falling or flowing or carried into the stream." (Rivers Pollution Prevention Act, 1876, section 5.)

1239.—*What is the restriction in the proceeding under this part of the Act?*

"Unless and until Parliament otherwise provides the following enactments shall take effect, proceedings shall not be taken against any person under this part of this Act save by a sanitary authority, nor shall any such proceedings be taken without the consent of the Local Government Board: Provided always, that if the sanitary authority, on the application of any person interested alleging an offence to have been committed, shall refuse to take proceedings or apply for the consent by this section provided, the person so interested may apply to the Local Government Board, and if that Board on inquiry is of opinion that the sanitary authority should take proceedings, they may direct the sanitary authority accordingly who shall thereupon commence proceedings.

The said Board in giving or withholding their consent shall have regard to the industrial interests involved in the case and to the circumstances and requirements of the locality.

The said Board shall not give their consent to proceedings by the sanitary authority of any district which is the seat of any manufacturing industry, unless they are satisfied, after due inquiry, that means for rendering harmless the poisonous, noxious, or polluting liquids proceeding from the processes of such manufactures are reasonably practicable and available under all the circumstances of the case, and that no material injury will be inflicted by such proceedings on the interests of such industry.

Any person within such district as aforesaid, against whom proceedings are proposed to be taken under this part of this Act, shall, notwithstanding any consent of the Local Government Board, be at liberty to object before the sanitary authority to such proceedings being taken, and such authority shall, if required in writing by such person, afford him an opportunity of being heard against such proceedings being taken, so far as the same relate to his works or manufacturing processes. The sanitary authority shall thereupon allow such person to be heard by hmself, agents, and witnesses, and after inquiry such authority shall determine, having regard to all the considerations to which the Local Government Board are by this section directed to have regard whether such proceedings as aforesaid shall or shall not be taken; and where any such sanitary authority has taken proceedings under this Act, it shall not be competent to any other sanitary authorities to take proceedings under this Act till the party against whom such proceedings are intended shall have failed in reasonable time to carry out the order of any competent court under this Act." (R. P. P. Act, 1876, sec. 6.)

1240.—*Is the Sanitary Authority obliged to afford facilities for draining of factories into sewers?*

They are: "Every sanitary or local authority having sewers under their control shall have facilities for enabling manufacturers within their district to carry the liquids proceeding from their factories or manufacturing processes into such sewers.

Provided that this section shall not extend to compel any sanitary or other local authority to admit into their sewers any liquid which would prejudicially affect such sewers on the disposal by sale, application to land, or otherwise, of the sewage matter conveyed along such sewers, or which would from its temperature or otherwise be injurious in a sanitary point of view!

Provided also, that no sanitary authority shall be required to give such facilities as aforesaid where the sewers of such authority are only sufficient for the requirements of their district, nor where such facilities would interfere with any order of any court of competent jurisdiction respecting the sewage of such authority." (R. P. P. Act, 1876, section 7.)

1241.—*Has the Sanitary Authority power to enforce the Act?*

Section 8 of the R. P. P. Act, 1876, states:—"Every sanitary authority shall, subject to the restrictions in this Act contained, have power to enforce the provisions of this Act in relation to any stream being within or passing through or by any part of their district and for that purpose to institute proceedings in respect of any offence against this Act which causes interference with the due flow within their district of any such stream, or the pollution within their district of any such stream, against any other sanitary authority or person, whether such offence is committed within or without the district of the first named sanitary authority.

Any expenses incurred by a sanitary authority in the execution of this Act shall be payable as if they were expenses properly incurred by that authority in the execution of the Public Health Act, 1875.

Proceedings may also, subject to the restrictions in this Act contained, be instituted in respect of any offence against this Act by any person aggrieved by the commission of such offence."

1242.—*How are the legal proceedings connected with the Rivers Pollution Prevention Act, 1876, to be conducted?*

Sec. 10 states:—"The county court having jurisdiction in the place where any offence against this Act is committed may by summary order require any person to abstain from the commission of such offence, and where such offence consists in default to perform a duty under this Act may require him to perform such duty in manner in the said order specified; the court may insert in any order such conditions as to time or mode of action as it may think just, and may suspend or rescind any order on such undertaking being given or condition being performed as it may think just, and generally may give such directions for carrying into effect any order as to the court seems meet. Previous to granting such order the court may, if it think fit, remit to skilled parties to report on the 'best practical and available means' and the nature and cost of the works and apparatus required, who shall in all cases take into consideration the reasonableness of the expense involved in their report.

Any person making default in complying with any requirement of an order of a county court made in pursuance of this section shall pay to the person complaining, or such other person as the court may direct, such sum, not exceeding fifty pounds a day for every day during which he is in default, as the court may order; and such penalty shall be enforced in the same manner as any debt adjudged to be due by the court; moreover, if any person so in default persists in disobeying any requirement of any such order for a period of not less than a month or such other period less than a month as may be prescribed by such order, the court may in addition to any penalty it may impose appoint any person or persons to carry into effect such order, and all expenses incurred by any such person or persons to such amount as may be allowed by the county court shall be deemed to be a debt due from the person in default to the person or persons executing such order, and may be recovered accordingly in the county court."

1243.—*May either party appeal from the county court for the removal of the case into the High Court of Justice?*

It may. "If either party in any proceedings before the county court under this Act feels aggrieved by the decision of the court in point of law or on the merits, or in respect of the admission or rejection of any evidence, he may appeal from that decision to the High Court of Justice.

The appeal shall be in the form of a special case to be agreed upon by both parties or their attorneys, and if they cannot agree, to be settled by the judge of the county court upon the application of the parties or their attorneys.

The court of appeal may draw any inferences from the facts stated in the case that a jury might draw from facts stated by witnesses.

Subject to the provisions of this section, all the enactments, rules and orders relating to proceedings in actions in county courts and to enforcing judgments in county courts and appeals from decisions of the county court judges, and to the conditions of such appeals, and to the power of the superior courts on such appeals, shall apply to all proceedings under this Act, and to an appeal from such action in the same manner as if such action and appeal related to a matter within the ordinary jurisdiction of the court.

Any plaint entered in a county court under this Act may be removed in the High Court of Justice by leave of any judge of the said High Court, if it appears to such judge desirable in the interests of justice that such cases should be tried in the first instance in the High Court of Justice and not in a county court, and on such terms as to security for and payment of costs and such other terms (if any) as the judge may think fit." (R. P. P. Act, 1876, section. 11.)

1244.—*Is the certificate of the Inspector of the Local Government Board the best practicable means for advising on the subject?*

Yes! "A certificate granted by an inspector of proper qualification, appointed for the purposes of this Act by the Local Government Board to the effect that the means used for rendering harmless any sewage matter or poisonous, noxious, or polluting solid or liquid matter falling or flowing or carried into any stream, are the best or any practicable and available means under the circumstances of the particular case, shall in all courts and in all proceedings under this Act be conclusive evidence of the fact; any certificate shall continue in force for a period to be named therein not exceeding two years, and at the expiration of that period may be renewed for the like or any less period.

All expenses incurred in or about obtaining a certificate under this section shall be paid by the applicant for the same.

Any person aggrieved by the grant or the withholding of a certificate under this section may appeal to the Local Government Board against the decision of the inspector, and the Board may either confirm, reserve or modify his decision, and may make such order as to the party or parties by whom the costs of the appeal are to be borne as to the said Board may appear just." (R. P. P. Act, 1875, section 12.)

1245.—*What restriction is there on proceedings for offences?*

"Proceedings shall not be taken under this Act against any person for any offence against the provisions of Parts II and III of this Act until the expiration of twelve months after the passing of this Act, nor shall proceedings in any case be taken under this Act for any offence against this Act until the expiration of two months after written notice of the intention to take such proceedings has been given to the offender, nor shall proceedings under this Act be taken for any offence against this Act while other proceedings in relation to such offence are pending." (R. P. P. Act, 1876, section 13.)

1246.—*How are orders as to costs of inquiries issued?*

"The Local Government Board may make orders as to the costs incurred by them in relation to inquiries instituted by them under this Act, and as to the parties by whom such costs shall be borne and every such order and every order for payment of costs made by the said Board under section 12 of this Act may be made a rule of Her Majesty's High Court of Justice." (R. P. P. Act, 1876, section 14.)

1247.—*What powers have the Inspectors of the Local Government Board under this Act?*

"Inspectors of the Local Government Board shall, for the purpose of any inquiry directed by the Board under this Act, have in relation to witnesses and their examination, the production of papers and accounts and the inspection of places and matters required to be inspected, similar powers to those which the inspectors of the said Board have under the Public Health Act, 1875, for the purposes of that Act." (R. P. P. Act, 1876, section 15.)

1248.—*Do the powers of the Act prejudice those of other Acts in relation to water?*

They do not; for sec. 16 states:—"The powers given by this Act shall not be deemed to prejudice or affect any other existing or vested rights or powers in any person or persons or Act of Parliament, law, or custom, and such other rights or powers may be exercised in the same manner as if this Act had not been passed; and nothing in this Act shall legalise any Act or default which would but for this Act be deemed to be a nuisance or otherwise contrary to law. Provided, nevertheless, that in proceedings for enforcing against any person such rights or powers, the court before which such proceedings are pending shall take into consideration any certificate granted to such person under this Act." (R. P. P. Act, 1876, section 16.)

1249.—*What saving of rights of impounding and diverting water is made in the Act?*

"This Act shall not apply to or affect the lawful exercise of any rights of impounding or diverting water." (Sec. 17, R. P. P. A., 1876.)

1250.—*Under what modification Act is the R. P. P. Act, 1876, appilcable to Scotland?*

In the application of this Act to Scotland the following provisions shall have effect:—

(1.) The expression "Sanitary Authority" shall mean and include the local authority in any parish burgh in Scotland acting under the P. Health (Scotland) Act, 1867.

(2.) The expresion "London Gazette" shall mean Edinburgh Gazette.

(3.) The expression "the Public Health Act, 1875," shall mean the Public Health (Scotland) Act, 1867, and the Acts amending the same.

(4.) This Act shall be read and construed as if for the expression in "the Local Government Board" wherever it occurs therein, the expression "the Secretary of State" were substituted, and the expression "the Secretary of State" shall mean one of Her Majesty's Principal Secretaries of State.

(5.) The expression "the County Court" shall mean the Sheriffs of the county and shall include Sheriff's substitute and the expression "plaint entered in a County Court" shall mean petition or complaint presented in a Sheriff's court.

(6.) The expression. "the High Court of Justice" shall mean the Court Session in either division of the Inner House therefor.

(7.) All the jurisdiction, powers, and authorities necessary for the purposes of this Act are hereby conferred on Sheriffs and their substitutes.

(8.) The Court of Session may on the application of the Lord Advocate, on behalf of the Secretary of State, interpose their authority to any order made by the Secretary of State as to the costs incurred by him in relation to inquiries instituted by him under this Act and as to the parties by whom such costs shall be borne and may grant decree, conform thereto, upon which execution and diligence may proceed in common form.

(9.) An Inspector appointed for the purposes of this Act by the Secretary of State shall, for the purpose of any enquiry directed by the Secretary of State under this Act, be entitled by a summons signed by him, to require the attendance of all persons he may think fit to call before him in regard to the matters of the inquiry, and to administer oaths to, and examine upon oath, all such persons, and to require and enforce the production upon oath, of all documents, accounts, or papers in any wise relating to such inquiry, and shall also have, in relation to the inspection of places and matters required to be inspected, similar powers to those which sanitary inspectors have under the Public Health (Scotland) Act, 1867." (R. P. P. A., 1876. Part V., sec. 21)

1251.—*Under what provisions is it applicable to Ireland?*

In the application of this Act to Ireland the following provisions shall have effect:—

(1.) The "Sanitary Authority" shall mean any urban or rural sanitary authority acting in the execution of "the Public Health (Ireland) Act, 1874."

(2.) The expression "the Public Health Act, 1875," shall mean the Public Health (Ireland) Act, 1874.

(3.) The expression "the Local Government Board" shall mean the Local Government Board for Ireland.

(4.) The expression "the County Court" shall mean the Civil Bill Court.

(5.) The expression "Plaint entered in a County Court" shall mean Civil Bill process.

(6.) The expression "the High Court of Justice" shall mean any of the Superior Courts of Common Law in Dublin or any judge thereof to whom appeals may be brought from the decision of a Civil Bill Court.

(7.) The expression "the Judge of the County Court" shall mean the chairman of quarter sessions and judge of the Civil Bill Court.

(8.) The expression "the London Gazette" shall be the Dublin Gazette.

(9.) All the jurisdiction, powers, and authorities necessary for the purposes of this Act are hereby conferred upon the Civil Bill Courts and Superior Courts, and the judges of the same respectively.

(10.) All penalties, when recovered by or on behalf, or at the instance of or in any proceeding instituted by any sanitary authority, or any officer of such authority, shall be paid to such sanitary authority, and by the same applied in aid of their expenses under the Sanitary Acts: and, save as aforesaid, all such penalties shall be applied in manner directed by "the Fines Act (Ireland), 1851," and any Act amending the same. (R. P. P. A., 1776, Part VI, sec. 22.)

1252.—*What is the extent of the operation of the Public Health (Water) Act, 1878?*

The Public Health (Water) Act, 1878, applies to every Rural S. A., and also to such Urban S. A. as the L. G. B. may order (section 2). Every Rural S. A. shall see that every occupied dwelling-house within their district has, within reasonable distance, an available and sufficient supply of wholesome water. If the M. O. H. reports that an occupied house is without such supply, and the S. A. are of opinion that such a supply can be provided at a reasonable cost (the interest of which, at 5 per cent., shall not exceed twopence or threepence per week, as the L. G. B. may, on the application of the S. A., determine to be reasonable under the circumstances), the S. A. may require the owner (subject to appeal to the L. G. B.) to provide such supply within a specified time, and, in case of default, may themselves carry out the necessary works at his expense. It remains, however, the duty of the S. A. to provide any part of their district with a supply of water, in cases where danger arises to the health of the inhabitants from the insufficiency or unwholesomeness of the existing supply, and a general scheme of supply is required, and can be got at reasonable cost (section 3).

1253.—*What are the four agencies with which the Rivers Pollution Prevention Act, 1876, deals?*

It deals separately with :—

(1) Solid matters;
(2) Sewage;
(3) Trade effluents; and
(4) Mining effluents entering rivers.

1254.—*When may water-supply be enforced on lodging-houses?*

When the lodging-house is without a proper supply of water, and this can be furnished at a reasonable rate, the S. A. may enforce it (P. H. A., 1875, section 81). The keeper is required to limewash the walls and ceilings in the first week of April and October of every year (P. H. A., 1875, section 82). The S. A. may require the keeper of a house in which beggars or vagrants are received, to make returns of persons who have slept there the previous night (section 83), and the keeper must always give notice to the Medical Officer of Health and to the Relieving Officer of any case of infectious disease (P. H. A. 1875, section 84).

1255.—*Give a list of the Acts which relate to water-supply and to pollution of rivers, and state the special provisions of each.*

1. The Public Health Act, 1875.
2. The Public Health (Water) Act, 1878.
3. Rivers Pollution Prevention Act, 1876.

The first contains provisions (water-supply clauses) enabling an urban authority to provide a general supply of water for their district, to compel house-owners to avail themselves of such a supply when provided, either in urban or rural districts.

It vests the ownership of public cisterns, wells, reservoirs, etc., in the authority of the district in which they are situate Special and stringent powers are given to local authorities to prevent pollution of water by gas washings, and there is a clause empowering them to take proceedings in the higher courts to prevent pollution of streams.

Power is given to close polluted wells. Proceedings may also be taken to prevent nuisances, under the nuisance clauses, when a pool or water-course is so polluted as to be a nuisance, or in a state to be injurious to health.

The Water Act gives authorities power to supply or enforce provision of supply of water to any portion of their district, to a group of houses or a single house, and to prevent the occupation of new houses until provided with proper water-supply.

Right of entry is given for the purpose of ascertaining whether a house has a proper supply or not (an important provision omitted in the Act of 1875), and enjoins the duty of periodical inspection of water-supply.

Urban authorities may be invested with powers under the Water Act by the Local Government Board.

The Rivers Pollution Prevention Act consists of four principal parts :—

I. Prohibiting the putting of solid matter into streams so as to obstruct their flow or pollute the water.

II. Prohibiting drainage into streams of sewage.

III. Makes it unlawful to drain any objectionable liquids into streams, from factories or mines, or any obstructive or polluted solid matter from mines.

IV. Relates to administration of the Law. This, as well as previous parts of the Act, abounds with exceptions, provisoes, and provisions for repeated appeals which go far to make the Act ineffectual.

1256.—*Under what circumstances can Urban and Rural Sanitary Authorities supply gas and water to their districts ?*

The 38 and 39 Vict., cap. 55, sect. 51, (P. H. A., 1875,) recites that —'Any urban authority may provide their district, or any part thereof, and any rural authority may provide their district, or any contributory place therein, or any part of any such contributory place, with a supply of water proper and sufficient for public and private purposes, and for those purposes, or any of them, may—(1) construct and maintain water works, dig wells, and do any other necessary acts; and (2) take on lease or hire any waterworks, and (with the sanction of the Local Government Board) purchase any water works, or any water, or any right to take or convey water, either *within* or *without* their district, and any rights, powers, and privileges of any water company; and (3) contract with any person for a supply of water.'

Section 52 recites that if there is already a company supplying water to the district, the authority shall give the company written notice stating that they are desirous of supplying water, and the purpose for which and the extent to which the water is required, and then, provided the company are willing to supply the district with sufficient wholesome water, it shall not be lawful for the authority to construct other works.

Sections 53 to 67 deal with the various provisions as to supply, rating, penalties, etc, but section 62, being important to rural sanitary authorities, we here quote it :—

Section 62.—Where, on the report of the surveyor of a local authority, it appears to such authority that any house within their district is without a proper supply of water, and that such supply of water can be furnished thereto at a cost not exceeding the water-rate authorised by any local Act in force within the district, or where there is no local Act so in force at a cost *not exceeding twopence* per week, or at such other cost as the Local Government Board may, on the application of the local authority, determine under all the circumstances of the case to be reasonable, the local authority shall give notice in writing to the owner, requiring him, within a time therein specified, to obtain such supply, and to do all such works as may be necessary for that purpose, etc., etc., etc.

NOTE.—The ridiculously small sum of *2d.* per week being totally inadequate for the purpose named, renders this section inoperative in many rural districts, rural authorities being very averse to move the central authority in these cases, as that would at once call attention to that which is at present one of the crying wants of rural populations, *i.e.*, good water.*

1257.—*What is the object, and what are the main points, in the Rivers Pollution Prevention Act* (1876)*?*

The object of this Act is to improve and preserve the purity and flow of rivers and streams of Great Britain. It is applicable to all rivers, streams, canals, lakes, and water-courses, with the exception of water-courses at the passing of the Act mainly used as sewers, and emptying directly into the sea, or into tidal waters not declared to be streams within the Act. The four sources of pollution are—(*a*) Solid refuse of manufactories, manufacturing processes or quarries, rubbish and cinders, and any other waste or putrid matter; (*b*) Sewage matter, whether solid or liquid; (*c*) Poisonous, noxious, or polluting liquids proceeding from factories and manufacturing process; (*d*) Solid or liquid matter from mines which is poisonous, noxious, or polluting, or interferes with the flow of the water. Proceedings may be taken in England aganist the person causing the pollution in the county court of the district, or into a higher court with the permission of the judge of such court. L. A. must take proceedings against offenders, having first obtained the permission of the L. G. B. If the L. A neglect to act, any individual aggrieved may appeal to the L. G. B., who may or may not direct the L. A. to begin an action. Due regard will be paid to the industrial interest involved in the case, and to the circumstances and requirements of the locality. *This Act applies to Scotland and Ireland.*†

1258.—*What gave County Councils the same powers as Sanitary Authorities regarding the Rivers Pollution Prevention Act of* 1876*?*

The fourteenth section of the Local Government Act, 1888, which confers upon County Councils the powers of S. A.'s under the Rivers Pollution Prevention Act; and enables the L. G B. to form a joint committee representing all the administrative counties through or by which a river, or any specified portion of a river, or any tribu-

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*Model answer from the *Sanitary Record.*

†From HUSBAND'S *Medical Police.*

tary thereof passes, and to confer upon the joint committee all or any of the powers of a S. A. under the Act.

1259.—*What is there peculiar about the constant supply system of the East London Water Works Company?*

The East London Water Works Company have a section in the Act by which the company was constituted, that every person supplied with water on the constant supply system should, 'when required by the company, provide a proper cistern or other receptacle for the water with which he is so supplied.' This requirement of the company of a cistern from which water may be drawn for domestic purposes, irrespective of a cistern for water-closets, has been upheld by the Middlesex Sessions; and this company may refuse to supply water unless such cisterns are provided. This in great measure destroys the efficacy of the constant supply system.*

1260—*What power with regard to wells does the P. H. Act,* 1875, *give?*

Clause 70 of the P. H. A., 1875, gives power to close wells, tanks, cisterns, or pumps, if the water be polluted.

1261.—*What is the standard of purity of effluent laid down by the Rivers Pollution Commission?*

They recommend that 100,000 parts of the effluent water should not contain more than:—

In solution 2 parts of organic carbon per 100,000 parts.
0·3———N
In suspense 3·0———inorganic matter.
1·0———organic matter.

1262.—*What does the Rivers Pollution Prevention Act,* 1876, *demand in this respect?*

That the best practicable and available means are employed to make the sewage material innoxious.

1263.—*What does the R. P. P. Act,* 1876, *forbid as regards fluids, etc., entering rivers?*

(*a*) Solid refuse of manufactories, manufacturing processes, or quarries, rubbish, and cinders, and any other waste or putrid matter;

(*b*) Sewage matter whether solid or liquid; (*c*) Poisonous, noxious or polluting liquids proceeding from factories, and manufacturing processes; (*d*) Solid or liquid matter from mines, which is poisonous, noxious, or polluting or interfering with the flow of water.

1264.—*How may proceedings be taken under the R. P. P. A.,* 1876?

Only with the assent of the L. G. B. who are to have regard to the industrial interests involved.

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* From WHITELEGGE'S *Hygiene and Public Health.*

1265.—*In the case of country places and villages who are* 'de facto' *the Sanitary Authority?*

The poor Law guardians, that is, rural sanitary authorities.

1266.—*What points are laid down in the Public Health Act,* 1875, *with regard to the pollution of rivers?*

A sanitary authority can under clauses 68, 69, protect any water-course within its jurisdiction from pollution with gas or other sewage, but not from pollution by trade refuse. On the other hand, a sanitary authority can be indicted by landowners or others for creating a nuisance.

1267.—*Having constructed or purchased water works, what obligations are imposed on L. S. A.?*

Those of keeping the supply of water pure and wholescme (section 55 of P. H. A., 1875).

1268.—*What powers have Urban Authorities regarding the preservation of the purity of river water?*

Where any local Act other than an Act for the conservancy of any river is in force within the district of an urban authority conferring on any Commissioners, Trustees or other persons powers for purposes the same as or similar to those of this Act (but not for their own pecuniary benefit), all the powers, rights, duties, capacities, liabilities and obligations of such Commissioners, Trustees or other persons in relation to such purposes shall be transferred and attached to the said urban authority.

1269.—*What are the powers of Sanitary Authority regarding the pollution of streams by gas or sewage, and what are the penalties connected with such offences?*

Heavy penalties are imposed on any person or persons polluting any stream, pond, etc., with gas washings (section 68), and a local authority may proceed against any one polluting any water-course with sewage (section 69). A justice's order may be obtained for the closing of a well or cistern, the water of which is used, or likely to be used, for drinking or domestic purposes, when the water is so polluted as to be injurious to health.

1270.—*State the Acts which give statutory power to Local Authorities to supply and maintain a water-supply, and to protect the same from pollution; and state briefly the general purport of thier provisions?*

The Public Health Act of 1875, with which is incorporated the Water-Works Clauses Acts, 1847 and 1863, the Public Health (Water) Act, 1878.

Under the Act of 1875, any urban authority may provide all works necessary for providing the whole or any part of their district, or may contract for a supply of water, and they are empowered to charge water rates.

Where a house-owner has been required by notice to lay on a supply from the mains for domestic purposes, the authority may do the work and recover expenses.

A rural authority may be endowed by the Local Government Board, with power to provide a general, and where a general supply has been provided, may enforce supply to houses as above without obtaining special powers.

The Water-Works Clauses Acts provide powers for making regulations to prevent waste of water, etc., etc.

CHAPTER XI.

PURIFICATION OF WATER.

INTRODUCTION—NATURAL PURIFICATION—ARTIFICIAL PURIFICATION.

1271.—*Under what headings may the purification of water be considered?*

The purification of water may be considered under the headings of *Natural* and *Artificial Purification.*

1272.—*What are the Artificial methods of purifying water?*

Water may be artificially purified by various means, of which the following are the more important, *viz.*, *Oxidation*, *Distillation*, *Precipitation*, *Boiling* and *Filtration.* Two or more of these processes are often brought into co-operation.

1273.—*What circumstances may necessitate the purification of water?*

Excessive hardness, animal or vegetable organic matter in suspension or solution, and where there is suspicion of specific pollution.

1274.—*How may water be purified without filtration?*

The purification of water without filtration is not carried on in Great Britain on a large scale except by Clark's process.

1275.—*Briefly describe Clark's process.*

This consists in adding a certain amount of lime water to a water which contains calcium carbonate rendered soluble by the presence of carbonic acid. Spring waters in the chalk districts are all more or less "hard," and many of them contain such a large amount of calcium carbonate in solution as to be unfit for washing purposes. Such a water when it is to be rendered "soft" by Clark's process, is let into a tank or reservoir, where it is mixed with a proper proportion of lime water and allowed to settle, the whole of the calcium being precipitated as calcium carbonate.

1276.—*Classify the methods by which impure waters may be purified?*

- I. Natural. ...
  - Oxidation.
  - Subsidence.
  - Dilution.
  - Action of animal and vegetable life.
- II. Artificial..
  - Distillation.
  - Exposure to divided currents of air.
  - Precipitation.
  - Boiling.
  - Filtration.
  - Addition of chemical agents.

1277.—*What is meant by Oxidation of organic constituents of water?*

Although it is not practicable, in the case of a running stream, to trace the progress of the destruction of the organic material by oxidation, yet there is no doubt that an appreciable amount is so destroyed. Moreover, a considerable amount of the organic matter is consumed by fishes and by the microscopic animals which inhabit the water, or is converted into simpler compounds through the agency of plants of the higher or lower orders.

The effect of the oxygen of the air as a means of purification in the case of running streams is well known. It has been proposed to aerate artificially the water of storage reservoirs and other water used for domestic supply, and it is no doubt of advantage in the case of small uncovered reservoirs to arrange the outlet and inlet so as to promote a continual circulation of the water and to avoid stagnation; beyond this it is doubtful if very much is to be gained by artificial exposure of water to the air.

A water which contains no dissolved gases is flat and insipid, so much so that where distilled water is prepared for drinking, as, for instance, on shipboard, it is necessary to aërate the water. There is, moreover, no doubt that the oxygen gas which any water dissolves from the air when it is in contact with it, plays an important part in the destruction of organic matters derived from various sources.

Oxidation is a process carried on by nature for the purification of polluted water. It operates upon the class of impurities which, with one exception, have most to be feared, namely, organic matters liable to decomposition or already partially decomposed. The oxygen which is always dissolved in water exposed to the air, and the free atmospheric oxygen with which the organic matter is brought into contact by the motion of the water, combines with that organic matter, thereby converting it into harmless nitrates, nitrites, and carbonic acid. The more violent the agitation and more complete the aëration of the water, the more thoroughly will the organic matter be broken up and changed into these innocuous inorganic forms. In this way advantage may be derived from the introduction of cascades, weirs, and the like along the course of a conduit, or wherever else it may be convenient. The purifying agent is always at hand and in superabundance, it is only necessary to utilise it by bringing it into contact with the substances upon which it has to act. This essential contact may be encouraged by other means than the exposure and agitation just mentioned, but as they are associated with other methods of treatment, further reference to them will be deferred.

1278.—*What are the natural processes engaged in the depuration of polluted water?*

There are many natural processes at work in bringing about some degree of purification of water. For instance, the water of surface wells is merely the subsoil water that has filtered naturally through the superficial stratum of the soil. Surface well water may not be pure, but as a rule it is more so than the subsoil water itself. The natural processes effecting the purification of large volumes of water, such as those of rivers, tanks, and wells, are of overwhelming importance, for, by means of *dilution, oxidation, subsidence,* and by the *action of animal and vegetable life,* Nature endeavours to minimise the harmful effects we have associated with impure water.

1279.—*How may we artificially effect the oxidation of water?*

Oxidation is effected by exposing water in finely-divided currents to the action of air, to oxidise organic matter. "The water is simply poured through a sieve, or a tin or wooden plate pierced with many small holes, so as to fall in finely-divided streams; or, a hand pump is inserted in a cask of water, and the water is pumped up and made to fall through perforated sheets of iron." Oxidation is aided by agitation of water exposed to air. This is one of the chief means by which the contaminated water of rivers is rendered less harmful, for in their onward course dashing over rocks, anicuts, etc., they absorb more oxygen than still water. Advantage of this physical property has been taken in several places in Russia, where the water is allowed to flow down a series of steps, passing through wire gauze as it does so. Oxidation rapidly removes sulphuretted hydrogen, offensive organic vapours, and a certain amount of the dissolved organic matter.

1280.—*What effect has Subsidence in the purification of polluted water?*

By the physical process of *subsidence,* the suspended solid matters finding their way into tanks, etc., gradually sink to the bottom. This is one of the most active of the natural purifiers of large bodies of water. The influence of this factor is fully demonstrated by removing a little of the silt and filth from the bottom of a tank, or a large well, that has not been cleared for some years. The water of tanks and rivers, during rainy periods, contains a large amount of fine clay; this gradually subsides, and in finding its way to the bottom, carries with it much of the suspended organic matter.

1281.—*Do all suspended matters subside with equal rapidity?*

They do not; chalk and sand subside sooner than clay: vegetable matter sooner than sewage and animal matter. The last-named being in a state of very fine division and specifically lighter, falls still more slowly, but both are easily removed by filtration.

1282.—*To what extent does Dilution purify waters?*

Dilution is efficacious only when large volumes of water are to be dealt with, and the contained impurities small in amount. The more concentrated the poisonous or harmful constituents of water, the more injuriously will they affect the consumers. This may appear to be a truism, but it is one that is too often lost sight of, especially in connection with tank and well supplies when these sources are decreasing in volume.

1283.—*What part do fishes and plants take in the purification of impure water?*

Fishes and plants ordinarily take no small share in purifying water, and for this purpose their presence in tanks and reservoirs may be looked upon as a necessity. In all large tanks a moderate amount of living plants is beneficial. Plants act chemically by aiding the oxidation of any organic matters present.

Tank water improves during the rains by dilution with rain water, and "the animal and vegetable life in it preserves the proper balance, removes decaying matters, and prevents putrefaction to any great extent; at least this is the case in good tanks." (DR. DAVID WALDIE.)

Of the water-plants suited for the preservation of tank water, the following are the best known :—*Nymphœa rubra*, which has long India-rubber-like stems, varying with the depth of water, and deep-red or blood-coloured runners; *Vallisneria octandra*, the water-plant used by the Jessore sugar-refiners to cleanse their raw sugars.*

In addition to the higher order of plants, there are a large number of cryptogamydous or non-flowering plants, such as *algœ*, *confervæ*, etc., which flourish in water, and generally in tanks or ponds, where they float about in masses, sometimes covering the whole surface with a thin green scum. They are harmless, in most cases in fact, beneficial. It is only during its decay that such vegetable matter is injurious to the quality of water. When clearing tanks or reservoirs of weeds, plants, etc., the vegetation should be entirely removed from the vicinity of the tank and not allowed to decay on the banks.

Fishes prevent the overgrowth of vegetable matter, and feed upon the insects and crustaceans, and the dead organic matter present in the water. According to RANKINE, destruction of fish contained in large volumes of water has led to increase in the number of small crustaceans on which the fish had lived, rendering the water impure and nauseous. In such cases the remedy is to re-stock the tank or reservoir with fish. Of fish, the best suited for stocking tanks are of the carp family (*cyprinidæ*).

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* This paragraph applies to the waters of Indian tanks.

The *algæ*, as a rule, including diatoms and desmids, are of little account unless they increase to a great extent and decay in the water. The fungi-plants destitute of green or other colouring matter, and growing upon or in the presence of decaying organic substances; the *infusoria*, or at least some of the forms of life included under this head; the bacteria, vibrios, etc., must be looked upon with suspicion, as they are found in waters known to be impure. It may be remarked that the processes of vegetation in rivers and lakes remove nitrates from the water.

1284.—*Tabulate waters according to the efficiency of the filtration in passing through various geological strata.*

1.	Chalk	3.	Green sand
2.	Oolite	4.	Hastings sand.

5. New red and conglomerate sandstone.

1285.—*What means are advocated to get rid of organic matters?*

1. Exposure to air;
2. Boiling and agitation;
3. Addition of common alum;
4. Condy's red fluid, and astringents such as ferric chloride and the fruit of the *Strychnos potatorum.*

1286.—*Enumerate some other methods of purification of water?*

Among other purifying agents may be mentioned distillation, the exposure of water in minutely-divided currents to the air, the immersion of pieces of charcoal or of iron wire, and the effects of plants and fish. In store reservoirs, the presence of a moderate quantity of living plants exerts a decidedly purifying influence, while the destruction of fish has been followed by an excessive multiplication of the small crustacean animals on which the fish had lived, thereby rendering the water nauseous and impure. The remedy was found in re-stocking the reservoir with fish. (RANKINE.)

1287.—*How may water be purified without filtration?*

1. By exposing it to finely-divided currents of air to oxidise the organic matter.
2. By distillation.
3. By boiling.
4. Addition of alum to the water.
5. " " hot iron*

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* This gives a chalybeate taste to the water.

6. Addition of Condy's fluid.
7. " " vegetable infusions, especially tea.
8. Use of Strychnos potatorum.
9. Charring the inside of casks.

1288.—*Name another means by which natural purification of water is effected?*

A great cause of purification of many waters, which otherwise would be unfit for human consumption, is *Aëration.* This is effected by streams and rivers passing over rocks, waterfalls, weirs and other obstructions, by which the water becomes mechanically mixed with air, the oxygen of which has such a valuable purifying effect, by destroying the foul matter in solution. By this means, rivers that receive the sewage of towns, become more or less fit for human consumption after having passed for some distance down their course.

Aëration has been advocated in order to produce oxidation and prevent putrefaction. The 'aquarium' or 'jet' system is the best of the various methods suggested. By this means air is introduced in a fine state of division instead of being in large bubbles, as in the 'blowing' system.

1289.—*How has the natural oxidation in water been imitated?*

For the effect of the oxygen of the air as a means of purification in the case of running streams, *vide* Chapter II. It has been proposed to aerate artificially the water of storage reservoirs and other water used for domestic supply, and it is no doubt of advantage in the case of small uncovered reservoirs to arrange the outlet and inlet so as to promote a continual circulation of the water and to avoid stagnation; beyond this it is doubtful if very much is to be gained by artificial exposure of water to the air.

A water which contains no dissolved gases is flat and insipid, so much so that where distilled water is prepared for drinking, as, for instance, on shipboard, it is necessary to aerate the water. There is, moreover, no doubt that the oxygen gas which any water dissolves from the air when it is in contact with it, plays an important part in the destruction of organic matters derived from various sources.

1290.--*How may water be exposed to air in divided currents, and what is the effect of this process in the purification of water?*

The water is simply poured through a sieve, or a tin or wooden plate, pierced with many small holes, so as to cause it to fall in finely-divided streams, or a hand-pump is inserted in a cask of water, and the water is pumped up and made to fall through perforated sheets of tin. It soon removes hydrogen sulphide, offensive organic vapours, and, it is said, dissolved organic matter. This plan has been used in Russia on a large scale, the water being allowed to fall down a series of steps passing through wire gauze as it does so. In Paris, also, it has been employed on the small scale.

1291.—*What are the only methods of rendering a dangerously polluted water harmless?*

Distillation and boiling. The Rivers Pollution Commissioners have expressed their opinion that all the methods of purification by filtration, whether carried out by water companies on the large scale or by the consumer on his own premises, are inadequate to prevent the propagation of epidemic disease by water. Theoretically they may be considered some safeguard, but there is "not a tittle of trustworthy evidence to support such a view."

1292.—*Describe the ordinary form of distilling apparatus?*

It consists of a retort, the neck of which communicates with a spiral tube called the "worm," placed in the vessel which contains cold water. The water in the retort is raised to ebullition temperature, the steam given off is condensed in the worm, and the distilled water is collected in a receiver.

1293.—*How is the condensed vapour (steam) collected?*

As the condensation of the steam proceeds, the water of the cooler becomes heated, and must be renewed; for this purpose a tube descending to the bottom of the cooler is supplied with a continuous stream of cold water from above, while the superfluous water flows out by the tube at the upper part of the cooler. In this way the warm water, which rises to the top, is continually removed. The boiler is filled about three-quarters full, and the water in it can from time to time be renewed by the opening above; but it is advisable not to carry the process of distillation too far, and to throw away the liquid remaining in the boiler when its volume has been reduced to a fourth or a fifth of what it was originally. In exceeding this limit we run the risk of impairing the purity of the water by the carrying over of some of the solid matter contained in the liquid in the boiler.

1294—*State briefly how distilled water is prepared.*

By vaporising the water or converting it into steam by means of heat, and then condensing it again by the aid of cold. [Distilled water is "vaporisation, plus condensation."]

1295.—*Under what circumstances is distilled water used?*

Distillation of water is practised on boardship from sea water, and in certain places where there is great scarcity of rainfall. By distillation water is rendered almost absolutely pure. [In India and Great Britain this process has served no part in connection with the hygiene of water-supply, but we are of opinion that when the source of a water is impure and the impurities of an organic nature, distillation might with advantage be carried out on a small scale by means of a block tin apparatus. We have used such a vessel for some time in our analytical laboratory, and have every reason to be satisfied with the results. It might be used for drinking water only in private houses. Almost any form of apparatus will suffice, if fuel can be procured, to obtain enough water to support life; and if even the simplest appliances are not attainable, the mere suspension of clean woollen clothing over boiling water will enable a large quantity to be collected *At sea,* salt water is sometimes mixed with the distilled water from the *priming of the boilers, and occasionally, from decomposition of magnesium chloride (probably), a little free hydrochloric acid passes off. This can, if necessary, be neutralised by sodium carbonate.** On the coast of Chili and Peru (where it never rains) the sea water is regularly distilled for domestic use.]

1296.—*How is the distillation of sea water carried out ?*

The water is evaporated in a special apparatus and the vapor collected, rejecting the first part which comes over, as this is always impure. Distilled water is very "flat" in taste, owing to its containing no dissolved gases. It can be aërated by letting it drop a considerable distance from one cask into another, through small openings in the upper one, and by filtration through charcoal afterwards. [Non-aërated water is not so easily absorbed into the system as ordinary water, and occasionally causes illness.]

1297.—*Mention places where distillation is used as a means of purification.*

On boardship, by the evaporation and condensation of the sea water—the salts do not ascend with the water.

On the coast of Peru and Chili (where it never rains), water is regularly distilled for domestic purposes.

1298.—*What is the best plan of rendering a water known to be polluted fit for use ?*

By distillation; this is undoubtedly the best plan, for if properly carried out all danger is got rid of. It has been suggested that foul gases may be brought over from dirty water, and that even *bacteria* or their spores may be transmitted; this is doubtful. An outbreak of diarrhœa among H. M. ships in the harbour of Valetta (Malta) was attributed to impurities in the water distilled from the not over-clean water of the Grand Harbour. The distilled water was also complained of as "going bad" very quickly in the Soudan campaign; but there the dirty water of the harbour of Suakim was used, and in such a case there is great danger of the original water getting in if the apparatus leaks or is in any way out of order. All distilled water should be tested with a few drops of dilute nitric acid and silver nitrate; if no haze appears, then the watar may be considered safe: all other waters will give evidence of the presence of chlorine, by the formation of a precipitate, turbidity, or haze according to the amount; and so will distilled water (so-called), if it has been contaminated during the process of distillation, or by being received in vessels not perfectly clean.

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* PARKES' *Practical Hygiene*, 7th Ed.

1299.—*What caution is necessary?*

Care should be taken that no lead, zinc, or copper finds its way into the distilled water. Many cases of lead poisoning have occurred on board ships, partly from the use of *minium* (lead sulphide) in the apparatus, and partly from the use of *zinc pipes* containing lead in their composition. If possible, *block tin* should always be used.

1300.—*What are the disadvantages connected with the composition of distilled water, and how may they be remedied?*

As distilled water is nearly free from air, and is therefore unpalatable to some persons, and is supposed to be indigestible, it may be aërated by allowing it to run through a cask, the bottom of which is pierced with fine holes, so as to expose the water to the air. Plans for aërating the water distilled from sea water have been proposed by Normandy and others, and are used in many steamers. Organic matter, at first offensive to taste and smell in distilled water, can be got rid of by passing it through a good filter, or by keeping three or four days, or by the addition of a little permanganate solution.

1301.—*How does distillation affect the palatability of water?*

It renders it insipid from absence of gases and salts. This non-aëration may be remedied · on board ships it is now aërated on its passage from the boiler to the tanks, by allowing it to pass through perforated tubes.

1302.—*What are the effects of distillation?*

Distilled water has an unpleasant taste, and is said to be indigestible from its want of aëration. This can be remedied by exposure to the air in finely-divided currents, as, for instance, by letting it fall through a sieve. Distillation is the most universally applicable mode of purification. Even sea water can be utilised in this way.

1303.—*Does distillation completely purify water?*

It removes all the solid impurities, but all the volatile gases, CO_2, NH_3, etc., remain.

1304.—*How may a water of known impurity of a dangerous nature be made harmless?*

Distillation and boiling are the only methods of rendering a dangerously polluted water harmless.

1305.—*Discuss the purifying influence of boiling on water?*

Of all processes of purification, that of *boiling* is by far the most certain. With regard to its effects as a safeguard against diseases produced by microbes contained in water, we may state that, "in order to render our safety from micro-organisms practically absolute, it is only necessary to have our drinking water boiled. Many persons have a prejudice against boiled water in consequence of its flat and insipid taste, but these undoubted defects may be easily remedied by passing the boiled water when cool through any ordinary household filter, which will impart to the water its original freshness and palatability. In fact, nearly all the terror which micro-organisms are justly capable of inspiring, melts away when we remember that we can effectually combat them by heat. Thus milk and water, each of which may be infected with hurtful microbes, capable of doing so much mischief to mankind, can be rendered practically safe by merely submitting them to the process of boiling. Indeed, it cannot be widely known, that perhaps the two most effective private measures which can be taken in avoiding zymotic disease, consist in boiling all our milk and all our drinking water. By insisting upon these simple operations being systematically carried out, every family can render itself independent of the purity of our public milk and water-supplies, the safety and wholesomeness of which are altogether beyond the power of private individuals to control."* [It may be interesting to know that the insipid taste given to water by boiling is remedied by the addition of a little lime juice or sugar, or both.

Water containing much organic matter should never be used for drinking purposes without previous boiling; especially is this the case when there is an epidemic of cholera or enteric fever in the town or district. By boiling the water, we reduce to a minimum the possibility of the disease attacking ourselves. It not only destroys the organic impurities, but also causes a precipitation of much of the dissolved mineral matter.]

1306.—*What are the advantages of boiling as a means of purification of water?*

This plan is best next to distillation: it gets rid of calcium carbonate, iron in part, and hydrogen sulphide, and lessens, it is said, organic matter. TYNDALL'S experiments have shown that there are stages in the life of *bacteria* during which they can resist almost any moist heat. But as they soften before propagation a solution can be successfully sterilised by repeated boilings, so as to attack the several crops of *bacteria* in their vulnerable condition. Most *fungus* spores are killed by boiling. On the whole we may take it that water, even only once boiled, is in all likelihood safe, and, if repeatedly boiled at intervals, absolutely so.

1307.—*Is boiling of much use in the purification of polluted water?*

This is one of the safest methods of purifying water, particularly of destroying disease germs, although very great heat fails to destroy some. Prof. TYNDALL'S experiments showed that this is obviated by carrying out the boiling process at different intervals of time, and so effect a sterilisation of the water. This process catches the organisms at the different stages of their development.

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* *Sanitary Record*, 1888.

1308.—*State briefly the effects of boiling on water.*

Boiling will remove temporary hardness and destroy all microbes, and therefore all specific contagia. Some of the organic matter is carried down with the calcic carbonate. Boiled water tastes flat, and needs aëration like distilled water. Lime is thrown down more completely if sodic carbonate is added.

1309.—*If it is absolutely impossible to avoid the use of "suspicious" water, what precautions should be adopted ?*

To carefully collect, store, boil and filter it. Filtration will remove all the gross impurities at least.

1310.—*Can these defects be remedied, and how?*

They can, by causing it to flow through a cistern at some length, the bottom of the cistern being pierced with small holes to expose the water to the air.

1311.—*What special salt is removed by boiling ?*

Calcium carbonate if present is removed by boiling, in which case it is deposited as an incrustation on the inner surface of the kettle or boiler. [As regards the CO_2 in water, there is an objection to this method, as the heat decomposes the calcium and magnesium bicarbonates, and therefore the amount of CO_2 evolved is greater than existed in the water as free carbonic acid. On the other hand, it is impossible by heat alone to obtain all the oxygen and nitrogen. Boiling will remove temporary hardness and destroy all microbes, and therefore all specific contagia. Some of the organic matter is carried down with the calcic carbonate. Lime is thrown down more completely if sodic carbonate is added. Suspicious water should always be boiled before being used.]

1312.—*What is the effect of the boiling on the hardness of water, and how does it produce this effect ?*

The CO_2 gas is driven off and the calcium and magnesium salts which it held in solution are precipitated. The hardness lost, therefore, represents the amount of salts deposited plus the CO_2 itself which has been evolved.

1313.—*For what purposes are such chemical substances as lime and alum used ?*

For the purpose of purifying the water. [The effect that such produce is a mechanical one, the various matters in suspension, both organic and inorganic being thrown down with the precipitate which is formed on the addition of the material. The organic matter in solution remains unaffected by the process.]

1314.—*For what are chemical processes in connection with water chiefly used?*

Chemical processes are for the most part intended to remove excess of lime. Hard water may be softened, and at the same time deprived of all suspended matter, organic or mineral, by adding about 5 grains of alum per gallon. Calcium sulphate and a bulky precipitate of aluminic hydrate are formed, and carry down suspended matters. If no calcium carbonate is present, calcium chloride and sodic carbonate must be added previously. Perchloride of iron (2½ grains per gallon) acts similarly.

1315.—*What are the most common chemical agents used in effecting the precipitation of impurities from water?*

Various chemical agents are used in effecting the *precipitation* of impurities. The following are among the most important:—Alum; lime; preparation of iron; permanganate of potash, etc.

1316.—*How does alum act?*

The aluminious salts are very serviceable in removing suspended organic matter, if carbonate of lime is contained in the water. The addition of alum causes the formation of calcium sulphate and aluminium hydrate, both of which fall to the bottom, carrying with them other impurities. The amount of alum required is about 5 grains to the gallon. It is doubtful, however, as to whether alum has much effect on dissolved organic matter. If the water is not hard, a little carbonate of soda should be added in order that a precipitable substance may be formed. The action of alum on a turbid or muddy water is very striking—·0001 per cent. of it renders such water clear. *Carbonate of soda,* if added to water, throws down calcium carbonate, especially if the water is boiled. This agent has been used in India for precipitating the impurities of water for many centuries. [The carbonate of lime becomes the sulphate, and this, with the aluminium hydrate produced, entangles the organic matter and carries it to the bottom Aluminous salts are found to be very efficacious in removing suspended matters, whether organic or mineral. It combines with any suspended organic matter and precipitates it; this action is more vigorous if lime is present in the water. It is much used in China, where the turbid waters of the large rivers are extensively drunk after the addition of a little alum. When added to water containing chalk in solution, it forms a bulky precipitate of aluminium hydrate, which falls to the bottom, carrying with it suspended and floating matters.

1317.—*Does alum affect the organic matter in solution?*

It has little or no effect on organic matter in solution in the water.

1318.—*What effect has the immersion of iron wire and magnetic oxide of iron on water?*

This plan is said to decompose organic matter. Charcoal and ferric oxide are sometimes mixed.

1319.—*What effect has the immersion of red-hot iron or steel (such as the heated blade of a knife) on water?*

Red-hot iron decomposes water into H and O, the O in the "nascent" state, oxidising any organic matter that may be present.

1320.—*What is the effect of adding perchloride of iron to water?*

It has been found that the water of the Maas in Holland, which is turbid from clay and finely-suspended organic matters, and gives rise in consequence to diarrhœa, is completely purified by the addition of perchloride of iron in the proportion of about 2½ grains of the solid perchloride to 1 gallon of water. It is a powerful oxidising agent.*

1321.—*What special chemical salt may be used as an oxidising agent upon the organic matter contained in water?*

In connection with oxidation we may mention the use of *Condy's fluid*, which is a solution of permanganate of sodium or potassium. It is a powerful oxidising chemical salt, and is, at times, exceedingly useful in ridding water of the dangers associated with contained organic matter. "Pure Condy's fluid readily removes the smell of sulphuretted hydrogen, and the peculiar offensive odour of impure water that has been kept in casks and iron tanks." Its action on organic matter varies with the nature of this impurity. In some cases much of the animal and vegetable organic matter is rendered innocuous, in others the action is somewhat uncertain. The use of permanganate of potash frequently gives rise to a yellowish tint in the water, due to finely-divided peroxide of manganese in suspension This does not interfere with the wholesomeness of the water. A little alum will carry down the suspended matter. Filtration effects the same object. There appears to be no doubt but that if the impurity of water depends upon organic matter the use of the permanganate solution considerably reduces the dangers associated with its consumption. When a little Condy's fluid is added to pure water, it gives the water a beautiful purple colour, which colour is permanent. If organic matter is present in the water, however, the purple tint is soon lost, and will not remain permanent, until all the oxidisable organic matter has been thoroughly oxidised.

There are many cases in which it is very useful; and as the permanganate certainly removes smells and oxidises in the cold to-some extent, it is a very good introduction to the alum process, and does work which alum alone will not do. But it cannot be considered a complete purifier of water from all organic matters. Its oxidising power is, however, often useful in cleaning charcoal filters, as will be presently noted. If it forms a precipitate of manganic oxide, it also carries down suspended matters; but the formation of this precipitate is very uncertain. The action on the dissolved organic matters will, of course, vary with the nature of the substance; some of the organic matters, both animal and vegetable, will be oxidised; but in the cold it will not act upon the whole of these substances, and some organic matters are not touched.*

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* PARKES' *Practical Hygiene*, 7th Ed.

1322.—*What are the advantages of Condy's fluid?*

It is pleasant, odourless, non-poisonous and convenient to use.

1323.—*What are the chief objections to the use of permanganate of potash as a purifying material?*

One objection to the use of the permanganate is that it often communicates a yellow tint to the water, arising from suspended finely-divided peroxide of manganese. This is probably of no moment as far as health is concerned, but it is unpleasant. Sometimes the addition of a little alum will carry down this suspended matter; boiling may be used, but often has no effect. Sometimes nothing removes it but filtration.*

1324.—*What are the indications for the use of permanganate of potassium?*

In the case of any foul-smelling or suspected water, add good Condy's fluid, teaspoonful by teaspoonful to three or four gallons of the water, stirring constantly. When the least permanent pink tint is perceptible, stop for five minutes; if the tint is gone, add 30 drops, and then, if necessary, 30 more. Now allow to stand for six hours; and then add for each gallon six grains of a solution of crystallised alum, and if the water is very soft, a little calcium chloride and sodium carbonate, and allow to stand for 12 or 18 hours.*

1325.—*What is the effect of Condy's red fluid?*

It removes bad smells and probably some organic matters as well, by oxidation, as it readily gives up its oxygen: it may also form a precipitate of manganic oxide, and thus carry down organic matters. It may be used in foul-smelling waters, by adding a teaspoonful to 3 or 4 gallons and stirring constantly till a permanent tint is left for five minutes; after this, filter through animal charcoal.

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* PARKES' *Practical Hygiene*, 7th Ed.

1326.—*What is the use of Condy's fluid as regards the quality of water?*

It serves both as a purifier and as a test of purity.

1327.—*In what simple way may Condy's fluid be used as a test of purity?*

Condy's fluid added to pure water gives the water a beautiful purple colour, which remains unaltered. But, if organic matter be present in the water, the purple tint is soon lost, and the Condy's fluid will not again show its purple hue on addition to the water until the organic matter has been thoroughly oxidised.

1328.—*What do you do before adding the solution?*

Acidulate the water with a few drops of hydrochloric acid.

1329.—*How long should the colour remain if the water be pure?*

For at least five minutes; if gone before this time, more must be added till the colour is pretty permanent; the amount required and the rapidity of discolourisation will indicate the nature and amount of the organic matter present.

1330.—*What effect has the organic matter on the permanganate of potash of the Condy's fluid?*

It dioxidises the organic matter, taking part of its oxygen, and being converted into manganate of potassium.

1331.—*How are organic matters best removed or treated?*

Organic matters in solution are best treated with potassium permanganate or Condy's red fluid. It readily removes any offensive odour arising from water kept in casks and oxidises at least a portion of the organic impurities which may be present, but as alluminium is only slightly affected by it without the aid of heat, it cannot be regarded as a reliable purifier of water tainted with animal impurities.

1332.—*What are the properties of $KMNO_4$ in purifying water?*

Potassic permanganate destroys effluvia and oxidises much of the organic matter in solution and suspension. Living organisms are for the most part unaffected by the quantities admissible in such a process. The permanganate should be added until a persisttent faint pink tinge appears; it is advisable to supplement it by alum purification.*

1333.—*What are the advantages of using Condy's fluid?*

It is simple, facile, does not impart any taste to the water and it is non-poisonous. It is added at short intervals until a faint pink colour remains permanently.

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* WHITELEGGE's *Hygiene and Public Health.*

1334.—*What are the ways in which potassium permangenese may be used in testing water ?*

1. For roughly indicating the amount of organic matter present by the time in which change of colour is produced.

2. In combination with alkalies, as alkaline permanganate in the albuminoid ammonia process of Wanklyn and Chapman.

3. In the presence of sulphuric acid, in which the amount of organic matter is expressed in terms of "oxygen required" to oxidise it.

1335.—*How does the addition of vegetable astringents act ?*

By coagulating albuminous bodies and organic matter in the water.

1336.—*How does the immersion of certain vegetable astringents in water affect it ?*

The *immersion or boiling of certain vegetables*, especially those containing tannin, such as tea, kino, the Laurier rose (*Nerium oleander*, which is rubbed on the inside of casks in Barbary), bitter almonds (in Egypt) purify water containing organic matter by forming an inert organic compound, a vegetable albuminate.

1337.—*What is the Strychnos potatorum and how is it used ?*

In India the fruit of the *Strychnos potatorum* is used, especially by the better class of Hindoos, to purify water. It is beaten into a paste, and rubbed on the inside of the water jar or cask. Dr Mouan says that it is chiefly used for the river water at the season when it is laden with silt, and that about 30 grains are used for 100 gallons of water, which act in twenty-four hours. Its action appears to be on suspended matters, which it possibly carries down by giving to the water a delicate albuminous coagulum, so that it purifies water on the same principle as beer is fined. Dr. O'Shaughnessy thought its action was connected with its astringency. Some experiments on its action were made at Netley, but without any satisfactory result. It did not even clear the water thoroughly from suspended matters, and it had no effect on the amount of nitrous acid, ammonia, or of oxidisable organic matters, as far as these could be judged of by potassium permanganate. Renewed experiments are, however, necessary.*

1338.—*Has charring the containing vessel any effect in purifying water ?*

It has: *charring* the interior of casks may be mentioned here as a means of artificial purification. This practice would enhance the purity of water stored in wooden cisterns.

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* PARKES' *Practical Hygiene*, 7th Ed.

1339.—*Name another method of effecting the purification of water without filtration?*

That of agitating the water with small fragments of coke, spongy iron or scrap iron, which purifies it from micro-organisms.

P. F. FRANKLAND's experiments seem to show that agitation with small fragments of certain substances effectually purifies water from organisms. *Coke* has a powerful influence, and so has *spongy iron.* Later, ANDERSON has shown that *scrap iron* is equally efficacious, so much so that it is now used at Antwerp in extensive water purification works instead of spongy iron.

1340.—*What is the origin of H_2 S in water?*

Decaying organic matter dioxidise any sulphates contained in the water; the O of the H_2 SO_4 or sulphate combines with the carbon of the organic matter to form CO_2 while the S unites with the H to form H_2 S.

1341.—*What other explanation is given regarding the occurrence of H_2S in water? May sulphides arise in water?*

Sulphides are said to result from the reduction of sulphates by *Beggiatoa*, and perhaps from contact with iron pyrites. Carbonic acid likewise liberates sulphuretted hydrogen from sulphides.

Hydrogen sulphide sometimes occurs in water as a consequence of the decomposition of sulphates by organic debris, even by the cork of the bottles used in collecting samples, the SH_2 being afterwards liberated by carbonic acid. In some mineral waters (Marienbad) hydrogen sulphide appears when *algæ* are in the water, but not without.

1342.—*How does sulphuretted hydrogen and marsh gas gain access to water?*

Sulphuretted hydrogen or marsh gas may be found, the former due to mineral sulphides such as pyrites, or to decomposition of sulphates by organic matter, the latter to fermentation of vegetable matter in stagnant pools, or to pollution by coal-gas. Traces of ammonia are usually present under the latter circumstance.

1343.—*How may we recognise H_2S in water?*

1. By its characteristic offensive (" rotten egg ") smell.

2. By the black streaks on the surface of the water produced by the addition of a few drops of a solution of acetate of lead.

3. By the addition of a solution of Na OH and the one of nitroprusside of sodium, producing a violet purple colour. [The nitroprusside acts only on sulphides.]

1344.—*May the presence of carburetted hydrogen be easily ascertained?*

It cannot be readily detected if in small quantity in water, but

Tiemann says that warming the water to 110° Fahr. (44° C.) will enable the smell to detect coal-gas, when chemical re-agents fail. Generally there are other impurities, especially if it be derived from gas impregnation. In larger quantity it sometimes bubbles up from the water of stagnant pools, particularly if there be much vegetable matter; and, in the cases of some natural springs in petroleum districts, can be ignited.

1345.—*Is the volume of a given gas dissolved in water at a given temperature always the same?*

It is generally found to be approximately the same at all pressures, and the ratio of this volume to that of the water which dissolves it, is called the *co-efficient of solubility*, or *of absorption*.

1346.—*Does distillation render impure water absolutely pure?*

It does not; it leaves the solid residues below, but the vapour takes with it the CO_2, NH_3, and volatile bases.

1347.—*What are the characters of natural well aerated waters?*

Well aërated waters are bright, lustrous, and agreeable to the palate. This is especially the case with water from wells or springs, of medium depth, in calcic carbonate formations—the low temperature and greater pressure combining to increase the charge of carbonic acid. The absence of dissolved gases in distilled water renders it flat, dull and unpleasant to taste.

1348.—*To what do aerated waters owe their characters?*

The various forms of aerated water (of which soda-water may be taken as the type) owe their sharp characteristic taste and sparkling appearance to the carbonic acid they contain.

1349.—*What amounts of the gases enumerated in the answer are absorbed by 1 litre of water at 59° F. and 30 inches of mercury pressure?*

	Litres.
Ammonia	782·7000
Hydrochloric acid	457·8000
Sulphurous acid	43·5642
Carbonic acid	1·0000
Oxygen	0·0148

1350.—*How may coal-gas find its way into wells or water pipes?*

Coal-gas passing into the ground from leaking of gas pipes sometimes finds its way into wells, or even into water pipes. In Berlin, in 1864, out of 940 public wells, 39 were contaminated by admixture with coal-gas. A good instance is related by Mr. Harvey, where the main pipes were often empty and gas penetrated into them. Having regard to the cases in which gases from the soil (from leaking gas pipes, sewers, etc.) find their way into water pipes, it would seem important not to lay down water pipes near any other, or, what is better, have all gas pipes in sub-ways where they can be inspected.*

1351.—*How is aerated water prepared? What are the points of hygienic importance in connection with these waters?*

Aërated water is prepared as follows:—Carbonic acid is generated by the action of sulphuric acid on chalk, sulphate of lime being left behind. The carbonic acid is forced into the water which dissolves about five times its volume of the gas. [It is merely a solution of carbonic acid in water under high pressure. *Real* soda-water has 30 grains of bicarbonate of soda to the pint, and should only be used medicinally.]

We have seen an instance in which aërated waters were prepared from the unfiltered water of a marsh pond. An analysis of this water showed an abundance of dead animal and vegetable life, as well as disintegrating animal and vegetable debris.

The use of aerated waters, prepared from unfiltered, impure water, is no less dangerous than the use of the impure water itself. We repeat this assertion, as there is an erroneous impression abroad that aërated waters have a self-purifying property. This is a delusion. Aerated water factories should be thoroughly supervised by all local municipal authorities, and the filtering apparatus of these establishments carefully seen to. We feel convinced that it is much safer to use pure, filtered, drinking water, than the aerated waters generally met with. This may not apply to those of large municipal towns and cantonments, where such manufactories are strictly superintended, but it certainly does to small towns and municipalities, where strict supervision is absent.

CHAPTER XII.

FILTRATION OF WATER.

1352.—*What are the general means adopted in the filtration of water?*

Filtration may be carried out either on a large or on a small scale. On a large scale it is conducted in the filter beds of public water works, in which case *sand* is the chief filtering medium; and on a small scale it is carried on in domestic filters, in which the filtering material varies.

1353.—*Do all natural waters require filtration before being used?*

There are very few waters that do not require some form of artificial purification, before being used for drinking purposes. Rain water, if collected pure, water from mountain streams, primary springs, and well-preserved deep wells (if remote from inhabited houses), may be used without any preparation. So may that from the water works of most large towns, the water of these works having been tolerably well prepared by filtration before final distribution. In all other cases the water should be subjected to some form of purification before being used. It is positively dangerous to drink the water drawn from the large majority of superficial wells we see within small towns and villages, without previously boiling and filtering it.

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* PARKES' *Practical Hygiene*, 7th Ed.

1354.—*How do filters effect the purification of water?*

Some filters act merely mechanically; others both mechanically and chemically.

1355.—*How do the majority of these filters act?*

Both mechanically and chemically. The latter is effected in the oxidation of the organic matters. These filters remove both the suspended and dissolved matters, both animal and vegetable. The action in all is limited if the amount of organic matter in the water is large, and they require periodical cleaning.

1356.—*What are the essential conditions necessary to constitute a good filter?*

1. That every part of the filter shall be easily got at, for the purposes of cleaning, or of renewing the medium.
2. That the medium have a sufficiently purifying power, and be present in sufficient quantity.
3. That the medium yield nothing to the water that may favour the growth of low forms of life.
4. That the purifying power be reasonably lasting.
5 That there shall be nothing in the construction of the filter itself that shall be capable of undergoing putrefaction, or of yielding metallic or other impurities to the water.
6. That the filtering material shall not be liable to clog, and that the delivery of the water shall be reasonably rapid.*

1357.—*What are the various questions arising out of these six requirements of a good filter?*

The *first* of these conditions obviously sets aside all filters of the older, and what used to be the usual, pattern, where only a small layer of filtering material was present, which was cemented up so as not to be reached without breaking open the apparatus.

The *second* condition is fulfilled, so far as filtering power is concerned, by a number of media; with regard to bulk of material this is also fairly well attended to in the filters when loose material is used,—but where solid blocks are employed the size is often quite incommensurate with the work they are called upon to do.

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* PARKES' *Practical Hygiene*, 7th Ed,

The *third* condition is complied with by spongy iron, good samples of carferal, and some other materials,—but not by animal charcoal in the loose condition. As solid blocks, animal charcoal seems to yield less impurity to water than in the granular condition.

The *fourth* condition depends a good deal upon the relative degree of impurity of the water. The spongy iron on the whole lasts the longest.

The *fifth* condition demands that nothing organic shall be used in the construction of the filter, or in the packing of the interior. Iron or other metal must be protected from the action of the water.

The *sixth* condition is generally fulfilled when the material is loose and when the water is not too full of suspended matter. Sometimes sponge is used to arrest suspended matter, but it is so apt to get foul that its use had better be avoided. The block filters are very apt to clog, a slimy substance forming on their surface. This is partly obviated now by the use of asbestos strainers (as in the silicated carbon filter). Spongy iron is apt to cake unless kept constantly covered with water, but this is arranged for in the new forms of filter.*

1358.—*What are the evils associated with neglected filters ?*

All filters are repositories for the impurities of water—a form of dust-bin. They take up and retain the foreign matter they have separated from the water. It should be remembered that a filter may become the breeding ground of germs, and may thus, if not kept clean, give rise to the injurious effects it is intended to prevent. They all require regular and thorough cleaning. A foul filter is most dangerous, for in this state it gives to the water the impurities it had previously removed. A foul filter is worse than no filter at all; it is a water polluter, instead of a water purifier. Any form of filter that does not permit of free access to the filtering medium is defective. However bright and apparently pure a water may be, except it be from some primary spring remote from habitations, and on elevated ground, it should always be subjected to filtration, for a water may appear unimpeachable as to its wholesomeness, and yet contain the germs of disease, which good filters are capable of removing.

1359.—*State briefly what are the special qualifications of a good filter.*

It must present no facilities for holding dust or the poisonous particles of disease, if it retain one it is likely to retain the other.

It must possess every facility for the removal of its impurities as fast as they are produced.

It must be free from damp.

It must be well filled with daylight, from all points that can be charged with light from the sun, without glare.

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* PARKES' *Practical Hygiene*, 7th Ed.

It must be charged with perfectly pure air in a steady changing current.

It must be maintained at an even temperature, and must be free from droughts.

It must be charged with an efficient supply of pure and perfectly filtered water.

A house possessing the advantages named under these heads cannot *(cæteris parabus)* be far from a perfect healthy house. It is a house in which a disease can never be generated so long as it is kept up to its proper standard; in which disease, if it be introduced, will remain for the briefest possible period; and which, after disease has left it, will admit of instant and complete purification.

Some filtering media both remove organic matter from dilute solutions, and destroy it. This they effect by causing the O dissolved in the water to combine with the organic matter. Foremost among such bodies is charcoal.

1360.—*Is filtered water prone to putrefy ?*

It is, filtration, and still more filtration with boiling, lessens the keeping power of water, so that these processes should only be carried out a short time before the water is to be used. [The fact that filtration lessens the keeping power of water is of importance in the use of all filtered water.]

1361 —*What additional precaution is necessary with regard to filters ?*

All waters subjected to purification should be examined from time to time, to ascertain that the purifying process is carried on efficiently.

1362.—*Does simple filtration alone remove all risks in connection with the use of suspicious or dangerous waters ?*

Not by any means · it will clear the water but will not effect the destruction of those poisonous agents (disease germs, organic poisons, etc.) which are the essential sources of risk. The Rivers Pollution Commissioners have expressed the opinion that all the methods of purification by filtration, whether carried out by water companies on the large scale, or by the consumer on his own premises, are inadequate to prevent the propagation of epidemic disease by water. Theoretically they may be considered some safeguard, but there is "not a tittle of trustworthy evidence to support such a view."

1363.—*Does the action of filtering media continue ?*

All the filters after a time become clogged up, and have therefore to be taken to pieces and throughly cleansed ; or, if this cannot be easily done, they may be purified by passing through them a solution of potassium permanganate or Condy's fluid, with the addition of a few drops of strong sulphuric acid, and afterwards two or three gallons of pure or distilled water acidulated with hydrochloric acid. The charcoal in a filter may also be purified by exposing it for some time to the sun and air, or by heating it in an oven or furnace. In the spongy iron filter the filtering medium has to be renewed from time to time. The danger of the possibility of becoming clogged up is one inseparable from all domestic filters.

1364.—*Should the use of domestic filters be restricted?*

Yes; the use of domestic filters is only desirable when the purity of the water is open to suspicion. A filter should be emptied from time to time to promote aëration, and requires frequent cleansing and occasional renewal of the carbon or other medium. Cleansing may be effected by scrubbing the carbon block, if removable, then running an acid solution of potassic permanganate through it, followed by copious washing with very weak hydrochloric acid, and finally several gallons of water. In the "filtre rapide" the medium can be renewed without trouble.

1365.—*What constituents does filtration remove?*

Chiefly the suspended organic vegetable and animal matters, leaves, excreta of birds, a large part of the suspended animal and a small share of the absorbed organic and mineral matters.

1366.—*What was the opinion of the Rivers Pollution Commissioners in regard to the various filtering media?*

The report of the Commissioners appointed to inquire into the best means of preventing the pollution of rivers speaks highly of *fresh* animal charcoal, silicated carbon, carbide of iron, and spongy iron; but the more recent experiments of Professor Frankland have tended to show that the iron preparations and sand are far more to be depended upon than the others.

1367.—*Is the rate of filtration of importance?*

It is; because it materially affects the results. The effect of filtration will be almost inversely as the speed of filtration.

1368.—*In what way may the efficacy of a filter be tested?*

By the microscopical examination of water before and after filtration; this is of some importance.

1369.—*How has the efficacy of filtering media been tested and proved?*

By means of an arrangement called *a subsidence filter*. This consisted of a wooden box 12 inches square and 20 inches deep, containing 24 plates of steel zinc, ¾ inch apart. Each plate had six holes punched in it, 1 inch in diameter. The holes were near to the side, and had their edges turned up a little; the plates were so arranged that the holes were not opposite each other. A small tap came from just below the lowest plate. Another box like this, but without plates, was also constructed. Both boxes were charged with freshly-softened water, containing chalk suspended in it. The water took about eight hours to clear in the box without the plates, and was quite clear in the one with the plates at the end of twenty-five minutes. This box of plates was next used as a filter, by sending a slow stream of water charged with suspended chalk through it. About 11 gallons an hour of quite clear water could be drawn off. If the speed was increased much beyond this the water was no longer clear. To render the analogy between the filter acting entirely by subsidence and the common sand filter quite plain, the box without the plates had a piece of coarse wire-gauze stretched across it just above the tap. It was then filled with slate chips, and water containing chalk in suspension, as before, filtered through it. The action of this filter was exactly the same as that of the plate filter, except that more water could be passed through it in an hour without turbidity. If, however, more than about 15 gallons an hour were passed through it, the water was slightly turbid, and if the quantity was increased to 20 gallons, it was quite so. Some experiments, substituting very coarse sand for the slates, gave analogous results.

1370.—*After filtration is completed what precaution should be taken ?*

A most important point with regard to a supply of pure water, is that the water when purified should not be brought in contact with foul and germ laden air. This matter is frequently neglected, and cisterns are too often placed in the vicinity of latrines, water-closets, and ashpits, where the water contained in them absorbs most noxious gases and germs.

1371.—*What are the defects of small filters ?*

When the filters are too small they fail to do much good; and Letheby has given analyses which prove that small filters may be nearly useless. It appears undesirable to use charcoal filters on this account, and filtration through charcoal has frequently been a failure. *Spongy iron* has been lately very strongly recommended.

1372.—*May a filter affect water in the oppsite way to that in which it is intended to act ?*

It may. In both large and small filters the amount of matter in solution is often *increased* by passing the water through the filter, for unless the ordinary filtering material is frequently cleansed, the decomposed substances arrested in the pores of the filter are absorbed by the water.

1373.—*What may be stated with regard to the superiority of one form of domestic filter over another ?*

It is obvious that, for reasons of convenience, one filter may be preferable to the others according to circumstances. If the water is required immediately in considerable quantity, and is to be consumed at once, animal charcoal would be used, but would require frequent renewal, as is the case in the "filtre rapide." In the other cases, where the delivery is slower, the size or the number of the filters would have to be arranged accordingly.

1374.—*How may suspended inorganic and organic matters be got rid of?*

By subsidence and filtration: boiling, especially boiling plus filtration (as a rule) effectually removes any of the possible ill-effects of suspended and dissolved organic matter.

1375.—*When is the filtering power of filters mostly taxed?*

During rainy seasons and in winter.

1376.—*What are the materials used for filtration on a large scale?*

Sand, gravel, brick, stone or shingle, the depth of the whole varying from 5 to 6½ feet.

1377.—*What is the principal filtering medium of nearly all modern water works?*

Sand, and this holds good whether the supply be from gathering grounds, rivers, reservoirs, lakes or tanks. Sand forms a very satisfactory barrier to our infection by disease-producing microbes conveyed by water, and the experiments performed by Dr. Percy Frankland indicate this. The fact that deep well water contains but few micro-organisms is another indication of the filtering power of the soil. [In the analytical report given in the Appendix, the water from the hydrants showed an absence of any harmful impurities, except a few micrococci, notwithstanding that the water in its raw condition from the Hoosain Saugor Tank, Hyderabad, Deccan, contained much ammonia (both saline and albuminoid) and crowds of bacterioid organisms.]

1378.—*How does sand act on the Thames water as regards microbes?*

It removes 95 to 99 per cent. of the microbes present in that water.

1379.—*Upon what particular impurities does sand used as a filtering medium act?*

It is yet uncertain whether the action of sand on organic matter is at all chemical, *i.e.*, whether the organic matter is oxidised in its transit; considering the amount of air contained in the interstices of sand, and how finely the water is divided in its transit, some amount of oxidation is probable, but good chemical evidence in support of this view is yet wanted. Mr. Shield's experiments seem opposed to the probability of much chemical action. On dissolved mineral matters sand exerts at first, and when in thick layers, a good deal of action; much sodium chloride can be removed; and Professor Clark has stated that even lead can be got rid of by filtering through a thick stratum. Very finely divided clay seems to pass through more readily than any other suspended matters.

1380.—*What is the action of such a filter as that ordinarily used as a filter bed ?*

It is almost entirely mechanical, and this by acting as a strainer, by the particles of matter contained in the water adhering to the sand, and by subsidence within the interstices of the filter itself. It removes all the suspended matter, but only a small portion of the dissolved organic matters. There is a layer of oxygen which oxidises organic matter out first, but as usually carried out it only reduces the suspended matters.

1381.—*What is the active portion of the filter ?*

It is about half-an-inch in depth of the upper layer of sand, and this has to be removed in some cases every two months, washed with water, then relaid, and again used. It is the first half inch of the upper layer of sand then which has to be repeatedly removed.

1382.—*At what intervals should this be removed ?*

It depends upon the amount of sedimentary matter and other impurities in the water, but as a rule once every two mouths is sufficient.

1383.—*Can this removed sand be used again ?*

Yes, but it must first be either heated in a furnace or thoroughly washed in a properly constructed trough.

1384.—*After the water has been filtered on a large scale what is necessary ?*

That it be kept in covered reservoirs to keep it from the sun and from contamination. They should also be well ventilated.

1385.—*Describe the method of supply by filtration adopted by the London Water Companies.*

The water taken from the river at Hampton is passed into a storage reservoir of masonry, capable of holding several days' supply. It is important that the capacity of this reservoir should be sufficiently great, both to obviate the necessity of drawing water from the river when it is in flood, and therefore very turbid, and to allow time for the clarification of the water by the deposition of all its suspended matters. The five companies supplying Thames water to London have storage reservoirs of an aggregate capacity of 516 million gallons, capable of holding 7·3 days' supply, the average daily supply from these five companies being 70·5 millions gallons. From the storage reservoirs the water passes on to the surface of the filter beds, which consist of layers of fine sand (average thickness 3 feet) lying upon layers of gravel, fine above, but coarse below. In the coarse gravel are the open mouths of the outlet pipes, which convey the filtered water to the pumping stations, from whence it passes through iron mains to the metropolis or to a high level reservoir near London. The depth of water on the filter beds is never more than two feet; the average rate of filtration per square foot of filter bed being 1¾ gallons per hour. The upper layers of fine sand must be frequently renewed, as they become choked with sediment. They are usually removed, and washed with water jetted from a hose under high pressure, before being used again in the filter beds.

1386.—*What effect have these filters on the microbes present in the unfiltered water?*

Dr. Percy Frankland has shown that the micro-organisms (harmless) present in unfiltered Thames water at Hampton are reduced in number on the average 97·7 per cent. by the storage and filtration which the water undergoes at the hands of the water companies, but that this reduction is largest in the case of those companies which have the largest storage capacity for unfiltered water, the greatest thickness of fine sand in the filter beds, the slowest rate of filtration, and the most frequent renewal of the filter beds—all these being factors of much influence on the chemical, as well as on the biological, characteristics of the water.

The conclusion that we may come to then, in the case of the London water-supply from the Thames, is that, as long as it is efficiently filtered, it is pure and wholesome; but that the Thames is not really a safe source of supply, for should the filtering arrangements break down at a period of epidemic prevalence in the upper reaches of the river, disease would in all probability arise amongst the consumers of the water in London. The same may be said of any other polluted river used as a source of drinking water.

1387.—*What is the usual plan of filtering water?*

The water is first collected into large settling tanks, and then filtered by ascent or descent, or both. The filters consist of brick tanks open to the air, and at the lower part the filtering layers are placed; the filter proper is usually from 3 to 5 feet in depth. The upper two feet or so consists of sand; the lower three, coarse gravel, becoming coarser and coarser as we pass down. Sometimes there is a layer of bricks at the bottom. The sand must be washed first with distilled water; white sand is the best, and, if possible, it should be heated to redness before use. The sand should be sharp and angular, and not too fine.

1388.—*Describe the construction and working of ordinary filter Public Water Works?*

The *filter beds* of public water works usually consist of a shallow tank, with stone or brick walls, lined with cement or concrete. The floor, lined in the same way, is grooved with small channels, leading to a main exit channel. Clean gravel, coarse below and fine above, is laid to the depth of three feet, and over this fine clean sand to a depth of three feet. The water that is to be filtered is allowed to flow over this to a depth that should not exceed two feet. Two filters are usually constructed alongside one another, so that one may work when the other is being cleaned. The filtered water is stored in a covered, cement-lined, tank. From this latter reservoir the water is distributed to streets and houses in iron pipes. Iron pipes are used because they are less expensive, and more convenient than stone ones, and can be carried over undulating ground. A further advantage is that they can bear greater pressure. The iron pipes should be bedded on a firm foundation to prevent leakage at joints, and valves or taps must be provided at the summit of upward and at the bottom of downward curves to allow of the removal of air or of accumulated silt. Water pipes, especially in a descent, are likely to admit gaseous liquid or even solid impurities through leaky joints. Such pipes should have a solid foundation, and should not be laid in polluted soil or near drains; otherwise concrete beds are necessary for them. If the water is muddy, it should be permitted to stand for some time in a *settling tank*, so that the mud may subside before the water reaches the filter. Open distributing channels are always objectionable, as the water they convey can never be preserved from pollution.

1389.—*How is the bottom of the filter bed prepared?*

The bottom of the filter bed is prepared to suit the circumstances of its position. It must be made practically water-tight. This is sometimes ensured by laying concrete on the bottom, but quite as often by a layer of hard clay puddle 18 to 24 inches thick, over which a flooring of brick is laid; where the ground is more than usually bad, both the clay and the concrete may be used with advantage; when concrete is used the brick paving is not essential. Upon this flooring a central drain, running lengthwise, is laid with which are connected on either side small tubular drains of 6 to 9 inches diameter, prepared for this purpose, the sides being pierced with holes to facilitate the entrance of the water. These side drains are laid nearly at right angles to the central drain, and from 8 to 12 feet apart. The central drain is frequently a double drain, performing two offices—the lower part, which is covered, gathering the filtered water, and the upper part, which is open, delivering the unfiltered water upon the sand, when refilling a filter bed immediately after cleansing, and in use then only for that special purpose. This central drain is sometimes of brick, and sometimes of stone covered with stone flagging, the side walls of the lowest 12 inches of the drain being in either case laid dry; the water-way for this size of filter should not be less than 30 inches wide by 15 inches of height.

1390.—*What are the objects and results of filtration on the large scale, and how are they carried out?*

On the suspended matter, the action, although simple, is twofold In the first place, particles too large to pass into the interstices of the filter are arrested at the very outside; in the second place, and with regard to finer particles, the process is one of sedimentation and adhesion. It is well known that a turbid liquid will deposit sediment, not simply on the bottom of the vessel in which it is contained, but also upon the sides. In a sand filter, as the water passes slowly downwards, not in veins, but by percolation, the minute particles of suspended matter are attracted to and deposited upon the walls of the numerous vessels which are formed by the void spaces between the grains and sand. This is true even when the material of the filter is very coarse. If muddy water be passed slowly through a bed of single or broken stone, it will clear much more rapidly than if the subsidence takes place in an unobstructed basin.

While it is true that the action of a sand filter is exerted chiefly on the substances which are in suspension, it is also true that some effect is produced upon matter actually in solution. This effect has been very much exaggerated; and yet there is no doubt that, if properly managed, sand filtration is competent to remove an appreciable amount of dissolved organic matter. The action may be explained in two ways. In the first place, most porous substances possess the power of removing certain kinds of organic matter by something which may be called adhesion. The absorptive power for any substance is limited and soon reached, and the substance thus removed may by appropriate means be again brought into solution. Quartz sand, as we should infer, possesses the power to a slight degree only. The second method, by which dissolved organic matter is removed in the sand filter, is by oxidation. The substance is actually burned more or less completely, in part by the oxygen held in solution in the water, and in part by the air entangled in the interstices of the sand. Although in filling the beds with water, great care is taken to displace the air gradually, and as completely as possible, some must always remain in the concavities of the individual grains of sand and otherwise entangled. The extent of the action of a sand filter in this direction depends not only on the thickness of the filtering medium, and the rate at which the filtration takes place, but also, and in large measure, upon the frequency with which the filter is cleansed. The cleansing of the filter not only removes the accumulation of organic matter, which, if allowed to remain, would tend to injure the water, but also involves the aëration of the sand.

The filter beds should be properly constructed, especial attention being given to the sand employed, and should be cleaned with sufficient frequency. Settling basins of sufficient size will generally be necessary, and, for the best effect, the filter beds should be covered, and the filtered water delivered at once to the consumers, or, if stored, it should be stored in covered reservoirs of small size, which can be readily emptied and cleaned if occasion require.

The covering of the filter beds is a great advantage, as has already been said; the covering of the clear-water basin is to be regarded as a necessity; especially in case of all waters which are liable to considerable vegetable growth. It would seem that the spores of the *algæ* are not removed by the passage through sand; at any rate, if the filtered water be stored in a reservoir exposed to light, the *algæ* develop themselves anew, and the advantage once gained is lost. It is, however, confidently asserted that, if the water after filtration be stored in covered reservoirs only, no growth will make its appearance. This has certainly proved to be the case in Berlin, Altona, and other places in Germany, and in several localities in England as well.

Many analyses have been made to ascertain the effect of sand filtration upon the water filtered. In some cases the oxidation alluded to is sufficient to determine an appreciable decrease in the amount of dissolved organic matter which gives colour and unpleasant taste to the water. In view of what is actually accomplished in existing works, it seems to be best to regard the removal of colour and unpleasant taste as incidental and likely to vary very much according to the condition of the filter. If a sand filter removes completely all suspended matters without allowing the matter at first removed to contaminate by its decay the water filtered subsequently, it may be regarded as successful.

1391.—*How are the sides arranged in England ?*

In England the sides are usually paved with brick or stone to slopes of from 1 to 1 to 2 to 1. [In North Germany the side walls have to be vertical on account of ice, and the depth of the water over the filter beds is not less than 4 feet.]

1392.—*With what accessory should the drain pipes of the filter beds be connected ?*

With air pipes, to prevent them getting chocked with air.

1393.—*How is the overflow to filter beds best arranged ?*

At or near each angle, and should be commanded by sluices, so that the scum, especially that which with some waters is so prevalent in hot weather, may be readily cleared off by opening the leeward sluice when there is a breeze Drains should be provided also for drawing off the water from both above and below the sand, without passing it through the clear water well or tank.

1394.—*How may the workmen be admitted to get at the sediment and collect it ?*

The lowering of the water 12 to 18 inches below that surface will afterwards be sufficient to admit of the workmen removing the crust of sediment collected upon it.

1395.—*What arrangements are made for the escape of water from the pipes, while the water is being first let on upon the filter beds ?*

From the ends of the pipe drains, as well as from the end of the central drain, small cast-iron pipes of 4 inches diameter rise to the surface of the ground to enable the air to escape while the water is being first let on upon the filter bed.

1396.—*What should be the areas of the filter beds under varying conditions of consumption of water?*

When the flow of water through the system of filters during the twenty-four hours cannot be made uniform, that is to say, when, as is sometimes the case (in the absence of an intermediate clear-water basin), it varies with the consumption, being greater during the day hours than during the night hours, the combined area of the filter beds in that case should be made to meet the maximum or daylight consumption of the service an hour.

1397.—*What relation is there between size and efficiency of sand filter beds?*

The smaller the filter bed, the smaller will be the total area of filtering surface required for the particular duty. The materials available for construction and their cost, will also necessarily influence the dimensions to be adopted, and it must always be borne in mind that although there may be but one filter off duty it will frequently happen that another is nearly unserviceable. It is therefore found best to give a liberal area of filtering surface to be prepared for all the contingencies of the service.

1398.—*How should the filtering media in a filter bed be laid?*

From above downwards :—

Fine sand	2′ 6″
Coarse „	6″
Shells or fine gravel	6″
Coarse gravel	2′ 6″

[A filter bed may be described as a tank or reservoir several feet in depth, with paved bottom, on which are laid a series of non-jointed or perforated tubular drains leading into a central culvert. The drains are covered with a layer of gravel about 3 feet deep, over which is spread a layer of sand about 2 feet deep. The layer of gravel is coarse at the bottom, becoming gradually fine towards its upper surface, and the same relative gradation, as regards coarseness and fineness, is observed with regard to the sand. The water is delivered uniformly and slow, and in order that the filtering process may not be carried on hurriedly, the pressure is always kept down, the depth of water being seldom above 2 feet and in some cases only one foot.]

1399.—*What should be the position of the lateral and collecting drains?*

A little reflection will show that the lateral drains can hardly be placed too close together, for it is dersirable that the filtered water should flow to the collecting drains with as slow a velocity as possible; and the further these drains are apart, the greater must be the amount of water running through each drain.

1400.—*After leaving the filter bed what should be the course pursued by the filtered water till it reaches the mains?*

The filtered water from each filter bed should be delivered into a small well, whence it escapes into the proper conduit, and is carried either to a common clear-water basin, or directly to the pumps. The sluices at this well can be so arranged, by operating downwards instead of upwards, as to adjust the head of water actually in action upon the filter bed. When the filter is clean, 9 inches of head will produce the required flow through the filtering material; according as the sediment becomes deposited on its surface, this head has to be increased to 2 or 2½ feet, varying a little with the character of the sand. If the head be allowed to exceed 3 feet, it is because the surface is being rapidly closed; the weight of the water comes then into play upon the sand, induces the packing already referred to, and leads to the labour of loosening up the material during the process of cleansing. Sometimes when this amount of head is exceeded, the pressure leads the water to break through at points where some slight difference in the material gives it opportunity. It will then flow through in veins, damaging the filter bed; but such overstraining of the filters is rare.

1401.—*What rate of filtration is allowable in such a filter bed?*

Not more than 4·5 foot per hour; or the speed of filtration should not exceed 700 gallons per square yard of filter bed area in 24 hours.

Four-and-half feet vertical per hour should be the maximum of speed of filtration.

To efficiently filter the water it should not be allowed to pass the filter quicker than at the rate of about fifty gallons per superficial foot of area of sand surface in twenty-four hours; it requires frequent cleansing, which is done by removing a small quantity of the top layer of sand, which is thoroughly washed and again used after exposure to atmospheric influences. It should be remembered that the filtering medium must always be *thoroughly clean* to allow of efficient action. Water, either river or well, passed through such a filter as above described, should be equal to that supplied to the metropolis of London, which has to pass the test required by Act of Parliament and the examination by the Government water examiner.

1402.—*What should be the speed of the vertical descent of water in the filter beds?*

The speed of vertical descent should not be much above 6 inches per hour, nor should the rate of filtration much exceed 700 gallons per square yard of filter bed in the 24 hours, although some water companies filter at a much more rapid rate than this. In large works there are always several filter beds, to allow of some being cleansed while the others are in use. The sediment deposited on the surface of the sand requires to be scraped off at intervals, and at each cleansing operation about half-an-inch of sand is also removed.

A fresh supply of sand is added when the depth of the layer is reduced to an extent which threatens to impair the efficiency of the filter. It appears that proper filtration, carried on according to this plan, removes suspended impurities, and a certain amount of dissolved mineral substances, but whether dissolved organic matters are destroyed, or oxidised to any considerable extent, seems doubtful.

1403.—*Why should the velocity of filtration be slow? Specify what should be the actual rate of filtration.*

To ensure the perfect cleansing of the water by the filters, as well as to prevent any disarrangement of the materials of which they are composed. the velocity of movement of the water must be very slow. The average rate is half gallon a minute for each square yard of sand surface, which is equal to 3½ gallons an hour for each square foot of sand area of the filter bed. James Simpson, who may be said to be the originator of the method of filtering now in such general use in England, is of opinion that the filtering surface should be predicated on a rate of 72 gallons a day for each square foot of sand, which is equal to 3 gallons an hour a square foot.

1404.—*How long should the water be exposed to the filtering medium?*

The water should be in contact with the filter for about four minutes, and the rate of filtration should be such as to permit of this. The rate of filtration through sand affects the results materially. The effect of filtration will be almost inversely as the speed at which the filtration is effected.

1405.—*How may this be proved?*

By what may be called a subsidence filtration.

1406.—*How is organic matter affected by filtering process in the filter bed?*

Organic matters in solution are, to a small extent, oxidised in their passage through the filter bed, when the sand is clean and sharp. This action ceases when the particles of sand become encrusted with the impurities filtered out of the water; it is therefore most effective when the sand on the filter beds has just been renewed.

1407.—*In filter beds what quantity of water should filter through a square yard in 24 hours?*

About 700 gallons.

1408.—*How are the layers of filtering media arranged in the filter beds of the London Water Companies.*

	INCHES.
1. Upper layer—fine silicious sand ...	15—18
2. Lower layers—gravel increasing in size from that of a small pea to a middle-sized potato ...	20—24

1409.—*What is the speed of filtration permitted?*

Sixty gallons of water are allowed to pass through each square foot in twenty-four hours.

1410.—*What rests upon the floor of the filter bed?*

Upon the flooring of the filter beds, and covering the gathering drains as well as filling up the intervening spaces, a layer of broken stones is laid, large shingle or quarry spauls.

1411.—*What should be the size of the stones?*

The stone should not be larger than will pass through a 4-inches ring, nor less than will pass through a 2-inches ring, and they must be clean and free from earth or quarry rubbish.

1412.—*How often should filter beds be cleaned out?*

Filter beds will require cleaning out after they have been in operation for a length of time, varying from one week to six or eight, but which will depend generally upon the fineness of the medium, and the quantity and quality of the water that has passed through it. When clean an ordinary sand filter will require only two or three inches head to yield water at about the ordinary rates, but as the sand becomes clogged, this loss of head will increase, or if the head be maintained constantly, the yield will gradually diminish. Filter beds, especially those worked at a slow rate, will often be found to require cleansing before the yield becomes greatly reduced. This will occur mostly with bright water containing suspended organic matter which accumulates in the beds, and, in time, has an injurious effect even on the quality of the filtered water itself.

1413.—*If the source of supply is very impure—a polluted river, for example,—how may it be purified?*

By a preliminary purification by subsidence tanks it may be improved, and floating matters may be excluded by admitting the water into the tank from the river through a submerged sluice.

1414.—*Do spring waters and well waters need to be filtered?*

Usually they are sufficiently clear and free from deposit to need no adventitious aid to render them acceptable to the eye, and palatable. Indeed, such waters, when clear, are best delivered direct to the consumers, so as to avoid contamination by exposure and manipulation. It is otherwise with waters collected from large gathering areas, and with river waters. These both commonly contain so much suspended matter, and are so much discoloured, as to necessitate a preliminary treatment in order to render them clear, pellucid, colourless, and free from objectionable deposits. Hard waters, especially those from springs, and less often river waters, may also be improved in appearance and better fitted for domestic and manufacturing purposes, by being deprived of a portion of their mineral constituents before distribution to the consumers. This is best done by the Porter-Clark process. [Where water, efficiently filtered on a large scale, is distributed direct from the storage reservoirs on the constant system, the writer is of opinion that it is as a rule best to draw the water direct from the main supply pipe, and to use it without further filtration. But where the water is supplied on the intermittent system, and is consequently stored in household cisterns, it is often desirable to filter it before use. Also in times of epidemics it is desirable for safty to boil drinking water and filter it before use. More often than not, perhaps, a drinking water is rendered less pure by ordinary filtration; and nearly always household filters are placed in most undesirable situations, such as near sinks, in pantries, near kitchens, etc., *i.e.*, in impure atmospheres. Under these conditions the water is apt to absorb gases and vapours which give it an unpleasant flavour; and this is more particularly the case when the water is boiled. Boiling water when cooled in an impure atmosphere very quickly absorbs gases and vapours and thus it is notorious that water which has been boiled is not only very often vapid but positively nauseous in flavour.]

1415.—*Should water be allowed to pass through the filtering media from below upwards or from above downwards?*

The filter bed is usually filled with water from above by flowing it slowly upon the sand either from one point in connection with an overflow drain, or from several points on the side of the filter. It would be safer and more convenient as regards getting rid of the air, to fill it from below by means of the drains there; but if this were done with the uncleaned water it would distribute its impurities all through the filter. When the filter has been once filled it is not necessary to empty it entirely at each cleansing of its surface.

1416.—*How and when are the filter beds cleaned out?*

In large works there are always several filter beds, to allow of some being cleansed while the others are in use. The sediment deposited on the surface of the sand requires to be scraped off at intervals, and at each cleansing operation about half an inch of surface sand is also removed. A fresh supply of sand is added when the depth of the layer is reduced to an extent which threatens to impair the efficiency of the filter. It appears that proper filtration, carried on according to this plan, removes suspended impurities, and a certain amount of dissolved mineral substances.

1417.—*How is the sand kept efficient?*

Each filter bed, at short intervals varying with the condition of the water, must have the deposit which accumulates on the surface of the sand cleaned off or removed, and while any one of the filter beds is undergoing this cleansing process, the other remaining filters must be competent to deliver the required supply without overstraining their functions. If, then, there are six filters, five of them must be competent to the full duties of the service, and if eight filters, seven of them must be competent to this duty, on the supposition always that not more than one filter will at any time be off duty. Should the circumstances in effect render two unserviceable, the remainder must have area enough to meet the requirements of the case.

1418.—*How is the filtering sand cleansed?*

At each cleansing of the filter bed the sand is loosened by forks for some 6 to 8 inches in depth, and afterwards raked smoothly over.

1419.—*How is the sand washed and again rendered fit to be returned to the filter bed?*

For washing the sand previously to its replacement in the filter beds, various contrivances are used. One is an iron box or cylinder open at the top, and having a false bottom perforated with small holes. The box is charged with the sand to be washed, and water under high pressure is admitted underneath the false bottom through the holes in which it rises with great force, boiling up as it were through the sand. The agitation thus caused effectively loosens the dirt from the sand, and the former is carried away with the water, leaving only the clean sand behind.

In some works the dirty sand is placed in a heap on the sloping bottom of a shallow chamber about 10 feet long, 5 feet wide, and 2 feet deep. Water under high pressure is then directed against the heap of sand from a hose pipe by the man in charge, until it flows away clear over a small weir at the lower end of the chamber. Two chambers are used placed side by side, so as to be worked alternately.

1420.—*When is the sand which is gradually removed, replaced?*

When the original thickness of 30 inches of sand becomes reduced to 18 or 22 inches it is replaced and brought up to the original limits. The renewal is usually made once in six months, sometimes but once a year, as the convenience of the service may permit.

1421.—*In very bad waters how often has the sand to be cleansed?*

In the worst stages of the English rivers a filter bed has to be cleansed once a week, rarely oftener. The stuff, whether sediment or otherwise, intercepted by the filter, is found collected on the surface of the sand; in the process of its removal a thin paring of sand is necessarily taken with it, not exceeding from $\frac{1}{2}$ inch to $\frac{3}{4}$ inch in thickness. The impurities carried by the water are not found to have penetrated the sand. The paring of sand is usually cleansed and laid aside for future use, except when fresh sand can be procured at less cost than the washing of the sand. The thickness of the sand bed is allowed to be reduced by these repeated parings from 8 to 12 inches before it is renewed.

1422.—*What is the effect upon the sand if the cleansing is too long delayed?*

The sand is liable to pack close if the cleansing is too long delayed. In such case the weight of the water is felt upon the sand; in the usual state of the filter it is not so felt.

In all cases it ought to be cleaned or renewed at least every three months, and with impure waters much oftener, say, every week or every fortnight.

1423.—*How should water filter be cleansed?*

All filters when first taken into use require to be washed by passing from 10 to 20 gallons of fairly good water through them, according to the size of the filter, as the filtering medium generally yields something to water in the beginning. It is also necessary to ensure the removal of dust, &c., that may be in the apparatus. But after a certain time of use all filtering media not only cease to be efficient, but even in some instances give up impurity to the water passed through them; so much is this the fact that cases of illness have been traced to this source, and some persons have thought the dangers of filtration were greater than those of unfiltered water. There is no doubt that the practice of depending for years upon the efficiency of a filter, which has never been cleaned or had its material renewed, is fraught with danger; and there is still danger to be apprehended from many of the so-called "self-cleaning" filters, which, in the words of advertisements, "require no attention." There is a limit to the power of all filtering materials, and no implicit confidence can be placed in any of the methods vaunted as "self-cleaning."

1424.—*What are* FRANKLAND'S *views as to the effects of sand filtration?*

Frankland has shown that filtration through sand removes 95 to 99 per cent of the microbes present in Thames water.

This sand filter had some effect in lessening the dissolved constituents, both mineral and organic, but the effect was limited; it stopped organic matter after it had ceased to arrest lime. After a longer time it became useless, and required washing.

Ferruginous green sand is excellent, for it arrests all organisms at first; after thirteen days it arrests 88 per cent., filtration being carried on at the rate of 0·73 gallons per square foot per hour; after one month there is a reduction of organisms to the extent of 39 per cent., at a filtering rate of 1·14 gallon per square foot per hour. The efficiency of this sand is therefore greater than might have been supposed.

The effect on suspended matters, both organic and mineral, is certainly satisfactory. On dissolved organic matter it is less so. Mr. Witt's experiments show only a removal of about 5 per cent.

Some experiments were made at Netley on a sand filter of 1 square foot surface, and made in imitation of a London water company's filter, viz., 15 inches of fine, well-washed white sand, and 20½ inches of gravel, gradually increasing in coarseness. The first eight gallons were thrown away, so as to avoid the fallacy of including the distilled water with which the sand had been washed.

1425.—*How may the ordinary large filter bed be imitated for domestic use?*

A small sand filter, to which may conveniently be added a layer of animal charcoal, capable of removing suspended matters and some of the organic impurity may be constructed like a miniature filter bed, in an ordinary flower-pot.

1426.—*Is there any perfect filtering medium?*

There is not; such a material has yet to be discovered. Up to the present time no filtering material has proved practically available on the large scale, except sand. Various attempt shave been made to use other substances, but hitherto without marked success. We will, therefore, consider the general features of the process of sand filtration as practised at home and abroad.

1427.—*What other materials may be employed in the construction of filter beds?*

Magnetic carbide of iron gives excellent results, if covered by a layer of sand to intercept the suspended impurities. It must be worked slowly and intermittently, so as to renew the aëration. Filter beds of this construction converted the black and offensive water of the Calder into a bright and palatable water, which was until recently supplied to Wakefield. Spongy iron can be used on the large scale, but not, of course, intermittently, like other filters. A new modification of filtration through iron is known as the "Revolving Purifier." The "purifiers" are cylinders containing small loose pieces of iron, and having many projections from the inner surface. Their long axis, upon which they rotate, is horizontal or inclined, and the surfaces of the iron masses inside are kept constantly bright and clean by mutual friction. Water is passed slowly through the cylinders as they revolve, and is exposed to the action of the constantly fresh iron surfaces. After subsequent sand filtration to remove the iron, the purification seems to be very complete.*

CHAPTER XIII.

FILTRATION OF WATER—*continued.*

CHARCOAL AS A FILTERING MEDIUM.

1428.—*What is supposed to be the best and most convenient of all filtering media?*

Fresh burnt animal charcoal is perhaps the best of all filtering

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*WHITELEGGE'S *Hygiene and Public Health.*

media, and filters chiefly constructed of this material should always be used for lead-polluted water-supplies. The experience of Mr. A. H. Allen with the Sheffield waters is to the effect that no other substance is nearly so efficacious as animal charcoal for removing lead from water. In Maignen's 'Filtre Rapide' animal charcoal or carbo-calcis and asbestos cloth are used. Vegetable charcoal is far less efficacious than animal charcoal as a purifying agent. Seaweed charcoal is perhaps better than ordinary vegetable charcoal. It has a great power of freeing water from organic matter, and it does to some extent oxidise the organic matter, by virtue of the O in its interstices, but whether to a greater extent than can be accounted for by the oxidation always going on in water exposed to air is a debatable question.

1429.—*How is animal charcoal prepared? What are its properties as a filtering medium?*

This substance is prepared by calcining crushed bones in closed vessels; it is extremely porous, and exerts considerable oxidising action on dissolved organic matters in water, and bleaches colouring matters in solution. These properties, however, are evanescent, and rapidly disappear if the charcoal is not cleaned or renewed, especially if the water filtered through it is somewhat impure. Not only this, but the charcoal yields to water phosphate of lime, of which it is largely composed. The phosphate favours the growth of living organisms; so that water must neither be kept too long in the filter nor must it be stored for use after filtration. Animal charcoal has very little action on fresh egg-albumen; it has been reasoned from this circumstance, and probably with correctness, that animal charcoal does not prevent the passage of living disease germs through its substance. For these reasons filters composed of animal charcoal, whether in loose fragments or in compressed blocks, are not at all suited for domestic use. They require more care and attention than any domestic filter is likely to meet with.

Regarding animal charcoal, however, the late Professor PARKES considered it to be one of the best filtering materials. "The particles of charcoal should be well pressed together, and the passage of the water should not be too quick. Contact with the water for about four minutes appears sufficient. There is a large (and, if the layer of charcoal be deep enough, complete) removal of suspended matters, both mineral and organic; water even deeply tinged comes through a good charcoal filter very clear and bright. So also dissolved organic and mineral matters are removed by charcoal in the first instance. All evidence agrees in respect of that point. But then its power is limited, and after a time it ceases to be efficient."

1430.—*What are its disadvantages?*

The charcoal yields to water phosphate of lime of which it is largely composed. The phosphates favour the growth of living organisms, so that water must neither be kept too long in the filter nor must it be stored for use after filtration. Animal charcoal has very little action on fresh egg-albumen, it has been reasoned from this circumstance, and probably with correctness, that animal charcoal does not prevent the passage of living disease germs through its substance. For these reasons filters composed of animal charcoal,whether in loose fragments or in compressed blocks, are not at all suited for domestic use. They require more care and attention than any domestic filter is likely to meet with. Nevertheless no less an authority than the late Prof. PARKES considered animal charcoal amongst the best of filtering media for domestic use.

If water filtered through it be stored for any length of time, it is apt to undergo change for the worse. Organisms begin to develop—minute moving bodies and low forms of plants—which render the water offensive. It is also observed that water left long in contact with the charcoal is apt to take back impurities from it, and ultimately to become worse than before. It is, therefore, clear that the oxidation of the organic matter is not complete, and that either minute germs may pass through the charcoal, or that it yields to the water substance which favour the propagation of germs absorbed from the atmosphere. Probably both conditions are at work, the substances yielded being phosphates and nitrogen. Another point of great importance, bearing upon this part of the question, is that fresh, and we may say vital, organic matter is only partially arrested by charcoal, fresh white of egg, for instance, passing through with considerable ease. Charcoal is used either in minute fragments or made into solid blocks. Both act well, with the above limitations ; but the looser form appears to be much the better of the two, as the blocks are apt to clog, and require a good deal of cleaning and attention.

1431.—*What is the most important defect in the use of all charcoal filters ?*

The great defect of all forms of charcoal filters is that they speedily become inefficacious, and the charcoal must be frequently renewed or reburnt, else the fouled charcoal will, as Dr. FRANKLAND has shown, actually increase the amount of organic impurity in the water. Block-carbon filters (moulded carbon blocks) do little more than remove gross suspended particles, are not to be too much relied on, and should not be used except when no better filter can be found, as by the soldier on the march, to whom a small suction filter is invaluable.

1432.— *What form of charcoal is best for filters and what are the defects of charcoal filters ?*

Animal charcoal is the best, but its power is exhausted in from two to three months, when it does harm. It deals with some impurities only, minute vegetable formations (spores) are unaffected.

1433.—*What is the basis of most domestic filters ?*

Granular charcoal fused or made up of silica, charcoal, etc., into solid blocks.

1434.—*What is the disadvantage of these blocks ?*

They soon get clogged with organic matter, the effects are not lasting, they require to be often cleaned, dried, heated, etc., or renewed.

1435.—*How may they be cleaned ?*

By washing them with strong acids such as hydochloric or sulphuric, and afterwards with permanganate of potash solution.

1436.—*Which is the best animal or vegetable charcoal for filtering purposes ?*

Animal.

1437.—*What are its advantages over vegetable charcoal ?*

It is said to last longer, continuing to act well for 2 or 3 months, after which it causes deterioration rather than improvement in the quality of the water.

1438.—*Does it remove all impurities ?*

No : it deals only with certain impurities : minute vegetable organisms, and especially spores are said to be unaffected.

1439.—*How may we purify charcoal after it has been used ?*

By boiling it with hydrochloric acid—this destroys any contained organic matter and dissolves earthy salts.

1440.—*What are the chief objections to the use of charcoal as a filtering medium ?*

It soon loses its power, it is expensive (especially if used on a large scale). Animal charcoal soon gets clogged if the water contains much organic matter and then yields to the water the impurities it previously removed.

1441.—*How is it prepared for filters ?*

It is made into blocks.

1442.—*What are its two chief defects usually met with ?*

As a rule it is insufficient in quantity ; the blocks are too small for the amount of work demanded of them ; and (2) it is liable to clog.

1443.—*What may be said in regard to the use of block filters ?*

Block filters are generally undesirable but if used, they may be cleansed by carefully brushing the surface, pumping air in the reverse way, and treating with permanganate as above described. They are of various sizes, from small pocket filters to large-sized domestic filters delivering 30 to 50 gallons a-day. The pocket filters are useful as strainers, but their small size must make the duration of their oxidising power comparatively short. They ought to be frequently brushed and washed in clean water, with permanganate if possible.*

The best and apparently soundest carbon blocks may be traversed by flaws, or there may be crevices between the block and the sides of the filter which permit more or less of the water to pass through without oxidation of its organic impurities. All filters should therefore be tested by introducing a quantity of the finest animal charcoal, previously freed from lime by treating with strong hydrochloric acid, and stirred up in a large quantity of water.

1444.—*In what other way may block-filters fail?*

They may crack or fissure, and then allow the water to pass through unfiltered.

1445.—*Which filters clog most and which least?*

Those in which the filtering material is dense and compact and in which the particles of the filtering medium are in close juxtaposition. Those filters clog least where the filtering material is least, and the particles are small.

1446.—*What was the result of* Dr. PERCY FRANKLAND'S *investigation in connection with the use of charcoal as a filtering medium?*

Thinking that an examination of charcoal, which had been in use for some time as a filtering agent, might throw some light on its real function as a purifier of water, he obtained from the London Purifying Company samples of charcoal from a No. 4 filter which had been in continual use at a house in St. George's Square, Pimlico, for the month of November 1865 to the time when samples were taken out of it for his enquiries, that was for a period of exactly two years; so that about 292,000 gallons of water had passed through it. Now it appeared to be a matter of great importance to ascertain whether the filter still had the power of purifying water, and whether it contained any notable quantity of organic impurity locked up in the pores of the charcoal. He therefore examined the capabilities of the charcoal as a purifying agent, and he found that when water supplied by the East London Water Company was filtered through the charcoal at such a rate that there was about 3 minutes' contact, the water was not merely deprived of its colour, as shown by examination of it in a two-foot tube, but it was also deprived in the usual way of organic matter. This he ascertained by the permanganate test and by distillation with caustic potash. It was evident that the charcoal still acted as a purifying agent. He next examined the charcoal for organic impurity, for if it had been removing organic matter from water at the rate of only a-tenth of a grain per gallon, it ought to have contained within its pores a very considerable quantity, not less than 4 lbs. of organic matter. Dr. **FRANKLAND** said he had passed some of the London water through a stratum of animal charcoal, three feet thick, at the rate of more than 41,000 gallons per square foot in 24 hours, under a head of 30 feet. The charcoal was in granules, like coarse sawdust, and in the above-named instance more than one-half of the organic matter in the water was removed; and, on reducing the rate of passage of the water to one-half, one-fourth, or one-tenth, the proportion removed was scarcely increased. It appeared, from experiments, that wood or other vegetable charcoal is inert in its action on organic matter in water.

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* PARKES' *Practical Hygeine*, 7th Ed.

In the discussion of this paper, Dr. **LEATHEBY** said that a cubic foot of animal charcoal weighing from 50 lbs. to 52 lbs., held within its pores four gallons of water, and that he had found by experiment that it was necessary that the water, to be purified, should remain in contact with the charcoal for at least one minute. In Mr. **BYRNE**'s experiments the time had been two-and-a-half minutes. It was stated that the rate of filtration through the filters of the Water Purifying Company is 400 gallons a day, through a filter containing 80 lbs. of charcoal.

This was found to be the result of passing water through a thickness of five inches of animal charcoal of a degree of fineness similar to that used in sugar refineries, according to a paper read at the Institution of Civil Engineers, in 1867, by Mr. **EDWARD BYRNE**. The experiments Mr. **BYRNE** made were not considered conclusive of the case, for there seemed to have been some peculiar property in the water; but, however that may have been, the experiments certainly did show that, after a certain quantity of water had passed through the filter, the remainder was in worse condition after than before it passed through.

The purification of water passing through any filter bed takes place by reason of two separate actions upon it, first, by straining out of it the solid matter in suspension, and, secondly, by bringing the oxygen of the atmosphere to act upon it so as to change any decaying organic matter which it may contain in solution into inorganic and harmless substances. The best filtering medium, therefore, is that which at once excludes from its pores suspended solid particles and exposes the dissolved organic matter to the largest possible amount of atmospheric air. Fine sand, by reason of its heaviness, lies too compactly in its body to comply with the latter requirement, while in its surface it is too porous to exclude all suspended matter. On the large scale this is a matter of no practical inconvenience, because, although the solid matter may not be altogether arrested on the surface, but may penetrate the sand to the depth of an inch or two, it is easily removed by regular attention, but the case of a small household filter is quite different; here no such regular attention is given, or could practically be given, to remove the solid material and replace it from time to time with fresh material. Some substance, therefore, must be used which is closer in its texture on the surface and more open in its body than a sand bed is. Charcoal is a very porous substance, but the difficulty is to make the water pass through the pores; for when the charcoal is in the form of lumps, however small, the water passes through amongst the interstices of the lumps or granules and not through their pores, thus coating the surface of each lump or granule with the impurities of the water, and for a time, therefore, depriving the water of them, but afterwards allowing it to pass through unpurified, and even, after further use, giving off to it part of the accumulated impurities of the water which had previously passed through.

1447.—*From the various experiments recently performed summarise the disadvantges of charcoal ?*

1. It fails to filter off the smaller micro-organisms of water, which pass over into the filtrate.
2. Fresh egg-albumen passes through and over it quite unchanged.
3. The charcoal yields to the water phosphate of lime of which it is largely composed. The phosphates favour the growth of the living organisms.
4. After a certain period the charcoal gives back the impurities it previously abstracted; it is then a storehouse of impurities which may sometimes be of a dangerous character.

1448.—*Name another method in which charcoal has been used in the purification of water ?*

By charring the inside of casks. This is an effectual plan, and BERTHOLLET considered it more effectual than the immersion of pieces of charcoal; the charring can be renewed from time to time.

1449.—*What are the best filters made of ?*

Animal charcoal, magnetic carbide of iron, spongy iron, polarite, carbo-calcis. They are capable of removing almost all the suspended matters, and at least 40 per cent. of dissolved organic impurities, together with a considerable amount of salts, such as calcium carbonate and sodium chloride.

1450.—*Are these properties of animal charcoal as a filtering medium lasting ?*

No; they are evanescent and rapidly disappear if the charcoal is not cleaned or renewed, especially if the water filtered through it is somewhat impure.

1451.—*What material is most frequently used in domestic filters and in what forms is it used ?*

Carbon is the commonest of all filtering media, and animal charcoal is believed to have a far greater purifying effect than vegetable charcoal. Many efficient patterns of filters are made essentially of animal charcoal; others, equally good, depend upon silicated carbon, manganous carbon, or "careferal" (charcoal, iron, and clay). Maignen's "Filtre Rapide" has no carbon block, but the water is made to pass through a mixture of powdered charcoal and lime (carbo-calcis) supported upon an asbestos cloth; like other animal charcoal filters, it seems to have the power of removing lead. Magnetic carbide of iron is another efficient medium.

1452.—*How do charcoal filters affect the micro-organisms contained in the water?*

Micro-organisms are removed for the first week or two by sand, especially the green ferruginous variety of sand (P. FRANKNLAD). Dissolved mineral matter with lead and sodium chloride are removed when the sand is in thick layers and cleansed frequently; colour is lessened, and oxidation of organic matters may take place.

DOMESTIC FILTERS.

1453.—*What are the chief varieties of filters in the market?*

The filters in the market are very numerous, but the most important are the following:—

1. Those containing animal charcoal in granules or powder.
2. Animal charcoal compressed into blocks by admixture with silica and other substances.
3. Spongy iron filters.
4. Magnetic iron filters.
5. Those containing other substances of a nature chiefly mineral.*

With regard to the use of domestic filters, we should remember that nothing short of intelligent personal supervision will keep them working properly. Servants are too apathetic in such matters to attend to the required details.

1454.—*Enumerate some of the more common forms of domestic filter?*

1. Silicated carbon filter.
2. Spongy iron filter.
3. Purified animal or vegetable charcoal filter.
4. Magnetic carbide of iron filter.
5. Polarite filter.
6. Carbon block filter.
7. Maignen's *Filtre Rapide.*
8. Ordinary sponge filter.

1455.—*What materials are most efficient filtering media for small filters?*

For domestic filters the following materials are much more efficient than other media:—Spongy iron, magnetic carbide of iron, polarite and carferal; this latter substance being a mixture of iron, charcoal and clay; animal charcoal and its various combinations with silica.

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* PARKES' *Practical Hygiene,* 7th Ed.

1456.—*What are the chief effects of filtration?*

Removal of suspended matter, partial oxidation of dissolved organic matters; many filters also remove some of the dissolved saline matters such as ammonia, nitrites as well as NaCl, $CaCO_3$, $CaSO_4$ and $MgSO_4$, thus diminishing their hardness.

1457.—*How are the nitrates affected by filtration?*

They may be increased by the oxidation of nitrites.

1458.—*How may filtration of pipe water be carried out directly?*

By tap-filters, by placing small filters for home use in the course of the delivery pipe or they may be connected with the pipe. These are suited for high or end pressure. The filtering medium is usually charcoal or silicated carbon. One or two patterns act with moderate efficiency, but the small quantity of the filtering medium must necessarily militate against the permanent efficiency of any such filter.

1459—*How may we classify domestic filters?*

Household filters may be divided into three classes: *first,* those of small size, intended to be attached to the faucet, where the water is brought in pipes either from the service mains of a general supply, or from a tank in the building; *second,* the portable filters designed to occupy a more or less permanent position, and to be filled with water, either by a ball-cock or other similar arrangement, or by means of smaller supplies continually renewed, *third,* the more permanent and fixed devices which are inserted or built into underground or other cisterns.

1460.—*What may be said as regards the efficiency of filters connected with the water-tap?*

Filters which are made to be attached to water-taps, cannot practically do anything more than act as mechanical strainers and arrest all suspended substances which may be in the water. There is no material known which can be introduced into the small space of a tap-filter and accomplish any real purification of the water which passes through at the ordinary rate of flow. Of all the patent contrivances which have been proposed, there is probably, after all, none better than the form which has been in use for many years, which is filled with clean quartz sand, and is capable of being readily reversed and thus cleansed. Even animal charcoal in the quantity which admits of being readily attached to a faucet, has no advantage over such a filter.

It is proper to say in this connection that in case the water is delivered by service pipes from a general supply, it is not necessary that the filtration should take place at the faucet, for most of the materials used for filtration can be obtained arranged in filters of large size intended for insertion in the house service. Of course, the objection to this arrangement is the expense and the liability that when the filter has been once inserted, it will be dismissed from mind, and proper care will not be taken to maintain it in efficient condition.

1461.—*On the whole what is the best filtering material for household filters, and what conditions are necessary to make it efficient?*

On the whole, there is no better substance for ordinary household filters than animal charcoal. The charcoal should be renewed from time to time; how often, will depend upon the character of the water and the amount passed through the filter. If the coal be in blocks, the clogging of the pores will indicate the necessity for cleaning; if in granules (which on many accounts is preferable), it may be well to renew the charcoal once in six or twelve months, according to the amount of water used. In the case of a filter fixed with some permanence, it is worth while to have made a simple chemical examination, if there is reason to suspect the efficiency of the filter: this will indicate whether the work is still being properly performed. It is true in the case of these, as of filters, in general, that unless attention is paid to them, and they are cleaned at proper intervals, their presence is worse than useless.

1462.—*What filters fulfil all the requirements of good household filters?*

The filters which fulfil these conditions the best are the spongy iron carferal and magnetic oxide and carbide of iron.

1463.—*Should filters be placed inside cisterns?*

No; in such positions they are neglected, their very existence being sometimes forgotten with the result that they become excessively foul and pollute the water they are intended to purify.

1464.—*What are the objections to cisterns and pipe filters?*

They are too small for the demand.

1465.—*How may they be employed?*

By attaching to an ordinary large filter to the supply pipe and fitted with a ball-cock and self-feeding valve.

1466.—*Describe a good form of tap-filter recently invented.*

A tap filter ("the Gum") has recently been brought out by a firm at Leeds, which consists of a small chamber containing finely-divided quartz. It can be fixed to most taps easily, and it is reversible, so that when the water has passed through it for some time in one direction, it can be turned round, the object being to remove the deposit that has occurred in the meantime, by reversing the direction of the current. This little filter is said to answer the purpose for which it is intended very well, but it must be remembered that the only effect it can have is purely a mechanical one, and for that reason, it is a question whether its use ought not to be discouraged on account of the false security it may convey to the minds of the public.

1467.—*What are the disadvantages of filters placed in cisterns?*

Filters permanently fixed in cisterns are objectionable, as their existence is liable to be forgotten, and, consequently, they are neglected and little likely ever to be renewed or cleansed.

The result is they become excessively foul and defile the water they are intended to purify. Small filters attached to service pipes are useless for the purpose for which they are intended, as the medium is in such small bulk, that the water is long enough in contact with it to allow any purifying effect to take place It has been stated that such filters, if the filtering material be animal charcoal, will remove lead from water to some extent.

From the above it is obvious that all filters in which the medium is permanently sealed up ought to be discarded, and it must be remembered that all so-called self-cleansing filters are a myth.

1468.—*What precaution should be taken every now and then in the case of permanent cistern filters?*

In the case of a filter fixed with some permanence, it is worth while to have made a simple chemical examination, if there is reason to suspect the efficiency of the filter; this will indicate whether the work is still being properly performed. It is true in the case of these, as of filters in general, that unless attention is paid to them, and they are cleaned at proper intervals, their presence is worse than useless.

1469.—*Enumerate the substances used as filtering media?*

As filtering media various substances are used, such as animal or vegetable charcoal, a mixture of fine silica and charcoal, magnetic carbide of iron, "polarite," careferal, spongy iron, "carbo-calcis," various combinations of these agents, sponge, cotton wool, &c.

1470.—*What is the most common filtering medium used?*

Carbon is the commonest of all filtering media; and animal charcoal is believed to have a far greater purifying effect than vegetable. Many efficient patterns of filters are made essentially of animal charcoal; others, equally good, depend upon silicated carbon, manganous carbon, or "careferal" (charcoal, iron, and clay). Maignen's "Filtre Rapide" has no carbon block, but the water is made to pass through a mixture of powdered charcoal and lime (*carbo-calcis*), supported upon an asbestos cloth; like other animal charcoal filters, it seems to have the power of removing lead. Magnetic carbide of iron is another efficient medium. [BISCHOFF's spongy-iron filter, besides removing the organic matter, lessens the hardness, and often reduces nitrates to ammonia. CHAMBERLAND's filter is made of unglazed porcelain, through which the water is forced under the prossure of the water pipes.*]

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* WHITELEGGE's *Hygiene and Public Health.*

1471.—*What forms of domestic filters are largely used?*

Silicated carbon and manganous carbon block filters are almost universally used. They consist of animal charcoal compressed into blocks by admixture with silica or manganese. They do not yield so much phosphate of lime to water as the pure animal charcoal filters; but they tend to become coated with a layer of organic matter which clogs the open pores.

1472.—*What are the principal forms of filters in use?*

1. Animal charcoal.
2. "Careferal" (charcoal, iron and clay).
3. Maignen's (powdered charcoal and lime supported on asbestos cloth.)
4. Spongy-iron.
5. Unglazed porcelain.

1473.—*With regard to speed of delivery during filtration talulate the result of experience in animal charcoal, silicated carbon, and spongy iron.*

As regards rapidity of delivery, animal charcoal and careferal have the advantage over spongy iron and block filters in the following ratio:—

1. Animal charcoal, { Water runs through fairly well purified
2. Careferal, { in 2½ to 4 minutes.
3. Silicated carbon, average exposure, 15 minutes.
4. Spongy iron, ,, ,, 22 ,,

1474.—*Which form of filters give most rapid delivery of water?*

The filters formed of loose particles give a more rapid delivery of water than the spongy iron and block filters.

Regarding such filters the late Professor PARKES stated:—This is an objectionable plan, and ought to be abandoned. Pipe filters are those which are placed in the course of a supply pipe, and tap-filters those which are fitted on to a delivery tap. The objection to most of those filters is that that they are generally much too small for the work expected from them, as they are usually represented by a small cylinder of block carbon or a few ounces of animal charcoal. For proper filtration the only way is to have a full-sized filter attached to the supply pipe, with a ball-cock or similar apparatus for filling it. The object is of course two-fold,—first, to ensure that all the water drawn shall be filtered; and, second, to save the time required when the filter has to be filled by hand.

1475.—*What filters best fulfil the conditions requisite in a good filtering medium?*

Those which are composed of spongy iron, careferal, magnetic oxide, and carbide of iron.

1476.—*What is silicated carbon?*

It is the residue left after the distillation of bituminous shale—a coke mixed with mineral matters—two of carbon and one of mineral matters.

1477.—*Describe the "Silicated Carbon Filter." How does it act?*

The "*Silicated Carbon Filter*" is held in high repute and consists of compressed blocks composed of carbon, silica, aluminia, and iron. It removes organic impurities, colouring matters, and especially lead in solution. At the same time the water is softened. New blocks are easily fixed to replace the old ones. The period of their activity is said to be about three years, but it would be dangerous to trust to the potentialities of a single block for such a prolonged period. The same objections as are made against all block filters hold good for this one. [The compressed blocks used in this filter are composed of carbon, silica, aluminia and iron. They remove organic impurities, colouring matters, and especially lead in solution. They likewise soften the water. They are said to be efficient for from 3 to 5 years. New blocks are easily made to replace the old ones. This filter enjoys a good reputation. All block filters, however, are liable to crack or fissure and to allow unfiltered water to pass through.]

1478.—*What are the silicated carbon and manganous carbon block filters?*

They consist of animal charcoal compressed into blocks by admixture with silica or manganese.

1479.—*What are their advantages and disadvantages?*

They do not yield so much phosphate of lime to water as the pure animal charcoal filters, but they tend to become coated with a layer of organic matter which clogs the open pores.

1480.—*Of what does the filtering block of the Silicated Carbon Company filter consist?*

Of 75 per cent. of charcoal and 22 of silica, with a little iron oxide and aluminia.

1481.—*How are silicated carbon and charcoal block filters cleaned?*

Carbon and silicated carbon block filters are cleansed by thoroughly brushing the surface. After this they should be replaced and two pints of diluted Condy's fluid (1—4 parts of water) allowed to pass through the filter. Then about 2 or 3 gallons of boiled and filtered water containing an ounce of muriatic acid should be passed through the filter. Finally pure water should again be used to wash away the taste of the drugs used. The filter is then once more fit for use.

1482.—*What objections may be raised against the majority of silicated carbon and charcoal block filters?*

That there is not a sufficient quantity of the filtering material, they are liable to clog from accumulated organic and other matters, and lastly they may be split, fissured or cracked and so permit of unfiltered water passing through them.

1483.—*Describe the improved granular charcoal filter.*

The "*Improved Granular Charcoal Filter*" is an excellent form of filter. Its construction is simple, and its action efficient. The filtering medium is granular charcoal. [Almost all the different kinds of charcoal filters act efficiently, and indeed the same may be said of nearly all domestic filter media, when properly attended to.]

1484.—*Name some useful portable or pocket filters that may be used when travelling.*

When travelling, particularly in jungle districts, the small "Pocket Silicon Carbon Filter," "Portable Carbon Filter," or the "Stone Bottle Filter" is very useful. With regard to the latter, when in use it is placed in a large-mouthed vessel containing the water to be filtered. The water should be allowed to stand for a while before immersing the filter. The water filters through the porous walls of the bottle into the interior chamber. The filtered water thus provided is usually potable.

1485.—*Describe the "Magnetic Filter."*

In this the filtering medium is magnetic spongy protoxide of iron, combined with a small proportion of carbon, forming what is known as magnetic protocarbide of iron. Its chemical activity has not been found to have diminished after more than twenty years' use. It does not easily become clogged.

1486.—*What is the principle of* Col. CREASE's *Service Filters for land and sea?*

The principle of them all is a filter of strong durable material, which yields nothing to water, space for a large quantity of filtering material, and a rapid delivery. The small filters may be earthenware or iron, the latter being protected internally by a patent cement;—the larger tanks of iron protected in the same way.*

Col. CREASE, C.B., Royal Marine Artillery, has arranged some excellent forms of filters, both small, for barrack, hospital, or ambulance use, and large tanks for ships or for large bodies of men on shore.

Carbalite is now employed. By using a large quantity of the material, with a rapid delivery, a storage reservoir becomes unnecessary.

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* PARKES' *Practical Hygiene*, 7th Ed.

1487.—*Describe* Col. CREASE's *Patent Tank Filters.*

1. The tank is made of iron, lined with cement and is divided into three chambers. The two filtering boxes which it contains are filled with pieces of animal charcoal, one may be filled with animal charcoal and the other with sand and gravel. The upper perforated plates of the boxes are moveable, so that by means of screwed marking on rods attached to the fixed under plates, which are also perforated, the filtering media may be lessened or compressed to any extent according to the degree of impurity of the water. The water descends through one box into a small chamber at the bottom of the tank, which retains any deposit and then rises through the second box into the reservoir which contains the filtered water. The whole of the apparatus can be readily unscrewed, taken to pieces, and cleansed out when necessary, the joints being made water-tight by gutta-percha bands. Smaller filters on the same principle have also been patented by Col. CREASE. It is known as "CREASE's Patent Tank Filter" and is manufactured by Mr. BELLAMY, of the Tank-works, Mellmall, London. It is now largely used in the navy and is specially suitable for large buildings, such as asylums, work-houses, etc.

1488.— *What may be said in favour of* Col. CREASE's *Patent Tank Filter?*

That for simplicity of construction, adaptability to different kinds of water, rates of supply, and for efficiency, it can scarcely be improved upon.

1489.—*Mention a small domestic filter in much favour.*

One consisting of two glass vessels—the upper containing a filter-block of compressed charcoal and the lower, which can be used as a water bottle, the filtered water.

1490.—*Describe a common form of filter in use in India.*

Domestic filtration can be readily carried out in all households in India. A simple form of filter is made by suspending three earthenware chatties, one above the other, in a triangular wooden frame. The top chatty is kept half full of clean charcoal, the middle one half full of sand. Into the lowest one, the filtered water drops and is collected. A small hole is to be made in the bottom of the two upper *gurrahs*. The lower two should be covered with perforated earthenware plates, and the uppermost one with an unperforated cover. These exclude dust, and prevent birds, squirrels, mosquitoes and other insects finding access to the water. An arrangement of this kind keeps the water cool and pleasant, and permits of free admixture with air, thus removing the unpleasant and insipid flavour given by boiling if this has been previously carried out. Every two months the charcoal should be thoroughly washed, brushed and dried in the sun; or fresh charcoal should be used. The use of an oven for this drying process is convenient and very effective. As the active part of the sand in filtration is the upper half inch or so, this should be removed every four weeks, thoroughly cleaned and relaid, and every three months the entire quantity changed. There are many points in favour of this form of filtration if properly carried out. It is simple, inexpensive, easily constructed, and reliable, the filtering media can be easily got at, cleaned, or renewed. The materials for its construction can be obtained in any village. To be efficient, however, it must be carefully attended to. The covers must be kept on to exclude dust, bird droppings, mosquitoes, insects, etc. A clean vessel must be used in removing the water for use, and water should be removed from the lowest *gurrah* only. The *bheestie* if not watched may empty his *mussack* into the lowest or middle chatty, to obviate the trouble of reaching the uppermost one.* [We may here mention with regard to the domestic supply of water by hand that when bheesties' mussacks or *pakals* are in use, they add their quota of impurity. It is not easy to keep these bags clean and free from the possibility of polluting water. We have frequently seen mussacks ripped up, or cut into with the object of examining the interior, and almost invariably we found them lined with a thick layer of slimy organic matter. Besides the bheestie is not always particular as to whence he fills his bag.†]

1491.—*Describe the* CHAMBERLAND-PASTEUR *Filter?*

It is a porcelain cylinder through which the water is forced. It is, perhaps, the best of all domestic filters. Its construction is very simple, for it merely consists of five or six tubes or cylinders of fine unglazed biscuit porcelain or earthenware, which may be screwed on to the service tap, when the pressure of the water will force the fluid through the pores of the porcelain, and a fairly rapid rate of filtration results. It is most efficacious in removing even the finest suspended particles, for even the bacilli of anthrax and their spores are by it effectually removed from water. This filter acts purely mechanically. It appears to be inefficacious for the removal of lead from waters. The surface of the porcelain tube in a short time becomes covered with a slimy coating, even when an apparently clean water is filterd. This coating is, however, readily and quickly removed by removing the tube and brushing it, or by washing it with hydrochloric acid. The water which has passed through this filter is sterilised. The filter is employed for laboratory purposes where water in a state is required chemically pure. The bottom of the cylinder is connected with a water-main under pressure, the water issuing from the top.

In this filter the water, under pressure is passed through five or six solid porous earthenware cylinders. The filtered water is entirely freed from all suspended matters, including all kinds of bacterial organisms and their spores. The water is therefore sterilised, but the filter acting merely mechanically, there is no alteration in the chemical composition of the water. The filter is employed to sterilise pure waters for laboratory purposes where the water is chemically pure. The bottom of the filter is connected with a main under pressure, the water issuing from the top.

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* AUTHOR'S *Hygiene of Water and Water-Supplies.*

† *ib.*

1492.—*Describe* MAIGNEN'S "*Filtre Rapide.*"

The filter consists of a perforated hollow frame, covered with asbestos cloth, and fitted into a tinned iron or copper case. At the bottom of the frame is the outlet tube, which passes through a hole in the case, and to it is screwed the tap, thereby fixing the frame in the case. An air tube passes up through the frame, over which at the top is placed a perforated screen.

In the "*Filtre Rapide*" (MAIGNEN'S patent), otherwise called the "Carbo-calcis Filter,"* the active filtering agent is purified animal charcoal intimately combined with pure insoluble calx. It is rapid and efficient in its action, and at the same time very convenient to use in purifying water from organic matter, ammonia, lime, sulphuretted hydrogen, iron, lead, and most of the mineral poisons. It practically removes all the suspended matter. It is said to have some influence in removing bacteria. It reduces the permanent hardness of water. The filtering material should be renewed every three months or oftener, especially if the water is of suspicious quality, or drawn from shallow wells. All parts of the filter are accessible, and the asbestos cloth, upon which the filtering medium rests, may be heated to redness and so efficiently purified when foul.

The powdered animal charcoal, or other filtering medium, is laid over the strainer. The delivery of water through this filter is very rapid, and the asbestos and powder can be easily renewed at very small cost. This filter on the whole is one of almost perfect construction and after the first or initial expense, its working costs practically nothing. It is easy to manage, is not likely to get out of order, and can add nothing in the shape of impurities to the water.

1493.—*How should* MAIGNEN'S "*Filtre Rapide*" *be cleansed?*

Unscrew the tap at the bottom, remove the screen at the top, and lift the frame bodily out of the iron case. The asbestos cloth can be cleaned without being taken off the frame, either by directing a stream of water on it, or brushing with the soft brush, or cloth; but great care must be taken not to injure or tear it by rough handling; should it be injured, a new cloth can be substituted. Replace the frame as before, and resume filtering by again first using some of the carbo-calcis as above directed; it will be necessary also to clean and begin filtering with fresh carbo-calcis should the filter have been laid aside or not used for some time. Should the asbestos cloth become very dirty it can be untied, taken off the frame and roasted before a fire, to which it can be put close without fear of burning; it must be carefully reapplied.

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* This is the trade name given by the patentees to the material used as the filtering medium. Other media, however, may be employed, such as granular or fine charcoal placed over the asbestos cloth.

1494.—*How should* Maignen's "*Filtre Rapide*" *be used?*

The filter may be used either on or off an animal's back, on the ground, on a box, or attached to a wall, cart wheel, board, etc. In filtering, first nearly fill the filter with water, and then mix one or two packets of the carbo-calcis in a bucket of water, and pour it into the filter over the screen; next open the tap, and place a bucket under it; at first some of the carbo-calcis will come through, and so long as it does so, simply return the same water again into the filter; in a very short time the finely-powdered carbo-calcis coats the asbestos cloth all over, forming thereon a perfect layer. The water will then come through pure and fit for use; and once this is established it is unnecessary to put in any more carbo-calcis, or touch the filter probably for a week or more, during which time it will filter constantly with a good flow. If the flow materially slackens, however, it is a sign that the filter requires cleaning, and the frequent necessity, or otherwise, for that will of course depend upon whether the water used is comparatively clear or muddy. On the line of march, and after use, the filter should be allowed to empty itself completely by the tap. It is not intended that water should be carried in the filter. If the filter after use is not to be again used for some time, it should carefully be dried before being put aside.

1495.—*What is the advantage of the asbestos?*

It forms an excellent strainer, and can be heated to redness, so as to destroy all organic matter, as often as necessary, and be replaced. In the original patent, canvas cloth was used instead of asbestos, but it was found that it rotted and imparted organic impurities to the water.

1496.—*What is spongy iron?*

Spongy iron is a granular substance, very porous, and resembles animal charcoal in appearance. It is obtained from hæmatite iron ore by calcination.

1497.—*Discuss the question of its usefulness as a filtering medium?*

The spongy iron which forms the filtering medium of Bischoff's patent filter is obtained by roasting hæmatite ore, reduced without fusion at a low temperature by means of carbon, and thus rendered vesicular or spongy. It acts both mechanically and chemically. It is exceedingly successful in oxidising organic impurities. It has the power of destroying miscroscopic vegetable organisms, but many authors assert it does not remove them. It has been proved experimentally by Frankland that living bacteria or their spores in water are destroyed by contact with spongy iron. This is certainly true with regard to the bacteria of putrefaction, but whether it is so with regard to the specific germs of disease has not yet been proved. Until recently spongy iron was the only filtering substance known that destroys the bacterial forms of life. It removes lead. It also removes the inorganic and organic matter in solution, and in this respect is about equal to charcoal. But unfortunately animal charcoal has exactly the opposite quality with regard to bacterial life to that possessed by spongy iron. Spongy iron removes lead in solution, and reduces the hardness of the water. After the experience of four or five years, its purifying action remains unaffected ; but it is recommended that the filtering medium should be renewed about once a year. One condition of its use is, that it should be always covered with water to prevent atmospheric oxidation. Water will not deteriorate if left in contact with spongy iron.

The property possessed by spongy iron and the magnetic carbide and oxide of yielding nothing to water, no phosphates or other germ nutrients, is a most valuable one ; for the water, after filtration, can be stored for any length of time without any great deterioration from growth of microscopic organisms. The special fitness of the magnetic carbide of iron or of polarite for filtering a town water-supply on a large scale lies in the fact that, when once the beds of these materials are inside, they need never be disturbed or renewed, and thus an enormous amount of labour and expense are avoided. The aëration by intermittent filtration, which is essential for magnetic carbide of iron, if it is to retain its oxidising properties, must not be practised with spongy iron as the latter cakes on exposure to the air.

In a number of experiments conducted at Netley and continued over a period of eight months, it was the only one the effluent from which never developed bacteria or any form of organisms.

1498.—*What are the special advantages of* BISCHOFF'S *spongy iron filter ?*

BISCHOFF'S spongy iron filter, besides removing the organic matter, lessens the hardnesss, and often reduces nitrates to ammonia.

1499.—*What experience have we in regard to the use of spongy iron on a large scale ?*

One of the most interesting experiments on the purification of water on a large scale was made at Antwerp in 1881. The water was first passed through a layer of fine sand, and then through a filter of spongy iron mixed with gravel. This filter was, however, found to clog at the top rather rapidly and the iron also required somewhat frequent renewal. It was found on further experiment that the water could be purified more economically by scattering cast iron borings in the water as it flowed through horizontal revolving cylinders; these cylinders were furnished with projecting plates fastened at intervals round the inside; as the cylinder revolved the iron was scooped and discharged on reaching the top. The iron was in this process first converted into ferrous oxide by the oxygen in the water ; the ferrous oxide was next in part dissolved by the carbonic acid as bicarbonate, a salt very easily decomposed into ferric oxide, which finally precipitates carrying organic matter down with it, the precipitate being very easily removed by filtration through sand.

1500.—*What was the experience of the Rivers Pollution Commissioners on spongy iron ?*

They found that spongy iron filters not only considerably reduced the proportion of organic matter in water, but also reduced the hardness—in some cases as much as 50 per cent. They also found that nitrates and nitrites were reduced by spongy iron, a small proportion of their nitrogen being converted into ammonia. In this way all evidence of previous sewage or animal contamination was destroyed (*6th Report of the Rivers Pollution Commissioners*).

1501.—*How does spongy iron act chemically on water ?*

Spongy iron decomposes part of the water into H and O, the O acting upon organic matter; the spongy iron, however, gives some of its iron to the water, but the M_3O_3 takes it up. It must be kept under water or it loses its spongy character and cakes into a solid mass. Spongy iron thoroughly oxidises impurities and does not favour vegetable growth; it never yields to water the impurities it has removed or destroyed.

1502.—*What disadvantages has it ?*

It is slow in action; the water must be in contact with the spongy iron for a certain time for it to act; charcoal filtered in 2½ minutes what the spongy iron did in 22.

Most filtering media containing iron, give some of it to the water.

1503.—*How do some Water Companies obviate this ?*

By adding M_2O_3 to the media.

1504.—*What precautions are necessary with regard to the use of spongy iron ?*

The spongy iron must be kept covered over with water, and should be renewed about once a year.

1505.—*How is caking of the spongy iron prevented ?*

By means of a syphon the water is prevented from descending below a certain level.

1506.—*How are the traces of iron added to the water by spongy iron filters removed ?*

The water which has filtered through the spongy iron is deprived of the iron it may have taken up, by passing it through fine gravel, and pyrolusite, a crude oxide of manganese. (See answer to last two questions.)

1507.—*What was the late* Prof. PARKES' *opinion as to the advantages and disadvantages of spongy iron ?*

Spongy iron retains its efficiency for a long time, and, as in the filters made with it the flow of water is expressly limited with reference to the bulk of material, the difference is solely in relation to the greater or less impurity of the water acted upon. Its efficiency may generally be depended upon for a year, and, unless the water be very impure, even for a considerably longer time. The experiments (by cultivation) of Dr. P. **Frankland** would seem to indicate a much earlier failure of efficiency, and it would be well to have the water tested both chemically and biologically at intervals to be assured of the continued efficiency of the medium. When the limit of efficiency is reached, the only safe plan is to renew the charge of material, and it is generally advisable to provide for this renewal once a year or oftener, if examination of the water indicates the necessity of it; should circumstances arise, however, to prevent this renewal, the best plan for cleaning is to subject all the material to the action of fire up to a low red heat, then to wash the whole well, and return it into the filter. The cleansing with permanganate and acid *must not* be attempted.

1508.—*How is the caking now prevented?*

By means of a syphon the water is prevented from descending below a certain level. It may also be prevented by having a strainer if the water has much suspended matter.

1509.—*Is the spongy iron filter popular?*

Bischoff's spongy iron filter has come largerly into use. The water which has filtered through the spongy iron, is deprived of the iron it may have taken up, by passing it through fine gravel and pyrolusite, a crude oxide of manganese.

Spongy iron thorougly oxidises impurities and does not foster vegetable growth, nor yields to water the impurities it has removed or destroyed.

1510.—*What was the late* Prof. Parkes' *opinion as to the use of spongy iron as a filtering media?*

It acts upon water itself, decomposing it and setting free hydrogen,—the oxygen being afterwards given up to organic matter that may come in contact with it. Its oxidising power is very great, although perhaps a little slow. Experiments at Netley showed that it could be depended upon to remove the greater part of the dissolved organic matter, and with prolonged exposure the whole of it in many instances. It has not much effect on mineral matter, but removes lead. It yields a little iron to the water, which, however, can be removed by further filtration through prepared sand,—that is, sand or fine gravel with pyrolusite. Beyond this nothing is yielded to the water, which comes out quite clear and pure, and may be stored for a long time without undergoing any change or showing signs of the production of living organisms,—or in any way favouring putrefaction. Water left in contact with it does not deteriorate. It retains its filtering power a long time,—very much longer than animal charcoal. These qualities are fully confirmed by the biological experiments of P. Frankland. Such properties render it suitable for use on a large scale, and it has been so used in several places, as for example, in the Water Works of Antwerp. On the whole, it must be looked upon as one of the most powerful and lasting filtering media we have.

1511.—*What is carbide of iron, and what is its action?*

It is a filtering medium, prepard by roasting a mixture of hæmatite with saw-dust. In action it is very similar to spongy iron. [The same may be said of magnetic oxide of iron.]

1512.—*What effect has magnetic carbide of iron in oxidising dissolved organic matters?*

The magnetic carbide of iron has as a very considerable effect in oxidising dissolved organic matters in the water, converting them into nitrates and nitrites; and this oxidising action is greater the longer the water remains in contact with the particles of magnetic carbide, that is to say, the slower the filtration. The layers of sand effectually remove the suspended matters in the water, which thus reaches the magnetic carbide perfectly clarified.

1513.—*How is the filtering material of the magnetic carbide filter prepared?*

By heating hæmatite with saw-dust. The only objection to it is that it communicates a slight taste of iron to the water, but this may to some extent be prevented by passing the filtered water through sand mixed with native manganese oxide or pyrolusite.

[Spongy iron and careferal may be used as mechanical filters to separate suspended matters, but the magnetic carbide and oxide of iron should be used only as a chemical filter, to oxidise or remove dissolved impurities in the water. Careferal should be removed about once a year, or it may be purified by exposing it to a low red heat.]

1514.—*What substance is now gaining in favour?*

The magnetic oxide of iron produced on the surface of the metal by BARFF's process.

1515.—*Where is scrap iron used as a filtering medium?*

At Antwerp and other places on the continent scrap iron (ANDERSON's process) is now being used for filtering water on a large scale.

The scraps of iron are placed in a cylinder, which is caused to revolve on its long axis. The inner circumference of the cylinder is provided with short curved shelves reaching from end to end, which, when the cylinder is revolving, serve to direct a shower of iron through the water as it passes through the apparatus.

The water is then exposed to the air by flowing along a trough, so as to cause a precipitate (as ferric oxide) of the iron taken up in the revolving cylinder, and this precipitate is subsequently removed by filtration through sand.

1516.—*What other material very similar to spongy iron has lately been introduced?*

A very similar material called *polarite* has lately come into use. It contains about 50 per cent. of magnetic oxide and carbide of iron, combined with other insoluble mineral matters, and is capable of producing equally good results with those above described.

1517.—*What is peculiar about the action of polarite on micro-organisms?*

One of the most valuable properties of polarite is the power it possesses of sterilizing air that may be passed through it, and by the process of combustion already described, destroying all noxious germs. In the apparatus now being described, air is admitted to the tank containing the purified water, only through a "sterilizer," which is a box containing finely granulated polarite, placed above the level of the supply cistern, and communicating with the pure water tank by means of a pipe. Thus the sterilized air is admitted automatically, and the oxygen, freed from all germs, is absorbed by the purified water, causing it to become fresh and sparkling like spring water. This apparatus will supply 500 gallons per day.

1518.—*What are the special virtues of polarite as a purifying agency?*

It has good oxidising properties, and yields nothing to water which is favourable to organic life; but its lasting powers are inferior to spongy iron and magnetic oxide and carbide.

1519.—*How is polarite prepared? What are its properties as a filtering medium?*

The magnetic spongy carbon or *polarite* is prepared from a peculiar description of carbonate of iron found in certain parts of South Wales. In its original state it is hard, non-absorptive, and non-magnetic. It is carbonised in retorts, and treated by a patented process, and then granulated to the degree of fineness required. By applying water to the sample, the extraordinary absorptive powers can be seen, although the pores are so microscopic as to be invisible to the naked eye. In the pores of this material a process of combustion takes place, similar to that with spongy platinum; by this means impurities may be said to be actually burnt out of the water brought in contact with magnetic spongy carbon. That the material is actually magnetic to a high degree is proved by the action of the grains when brought under the influence of a magnet.

Its percentage composition is said to be as follows:—

Magnetic oxide of iron	53·85
Alumina	5·68
Magnesia	7·55
Water with a trace of carbon . . .	5·41
Silica	25·50
Lime	2·01
	100·00

It contains, therefore, no poisonous metal; is very hard, porous and absorptive. It extracts iron and lead from water, and destroys organic matter in solution. It is a powerful declorizer and deodorizer by virtue of the polarized oxygen contained within its microscopic pores. It is extremely durable and magnetic to a remarkable degree, and notwithstanding that iron is the chief element in its constitution, it will not rust.

There is reason to believe that polarite acts also as an electrolyte, breaking up the molecules of water into their elementary components, catching and condensing the oxygen and accelerating its revivification. This property has been disputed, and is now being investigated by Dr. Angell.

"That the material is rustless is proved by the production of a sample taken from the Acton filter beds, which has been subjected to the action of air and water for eighteen months. There are several methods of applying this material to the purification of water. The water-supply of towns can be purified on a large scale by passing it through filter beds, constructed in a similar manner to the ordinary sand filters, but with the addition of a layer of polarite at least 6 inches thick, mixed with an equal quantity of sand. The best mode of constructing such a filter is shown by *Fig.* 2. At the bottom are placed 4-inch common agricultural drain tiles, surrounded with broken stones, then a layer of gravel from 4 inches to 6 inches thick, 4 inches of sand, 12 inches of sand and polarite in equal parts, and lastly, 9 inches of sand, making a total depth of filter of 2 feet 9 inches to 2 feet 11 inches. Space must be provided above the sand for a depth of from 6 inches to 12 inches of water, according to the rate at which it is desired to pass the water through the filter. Such a filter will purify water at the rate of from five hundred to one thousand gallons per square yard in 24 hours, which is a higher rate than can usually be obtained with an ordinary sand filter. Considerable economy in the construction of filters can be secured by the use of polarite, for although that material costs more than sand, the area of the filter can be considerably reduced, owing to the greater rapidity of filtration; and the depth is also reduced from 8 feet, or 5 feet 6 inches, to practically 3 feet, thus greatly reducing the first cost."

The value of a porous magnetic oxide of iron that will not rust, can scarcely be over-estimated, as its powers as an oxidizer approach that of "spongy platinum." The potency of a substance as a purifying, deodorising, declorizing and filtering medium is dependent upon, and may be measured by, its power of occluding and polarizing oxygen. The occlusion or condensation of oxygen takes place upon all surfaces, both interstitial and superficial, consequently that material which presents the largest surface in the smallest cubical space is the most powerful purifier, provided it is composed of a proper substance.

Spongy platinum practically fulfils all the conditions necessary in a good filter, and in consequence is the most powerful purifier and filterer, and the best insoluble oxidiser known. The process of oxidation that takes place in the pores of spongy platinum is so active, that a ball of this material has been used to ignite inflammable vapours, without the application of any heat other than that generated in the pores of the spongy platinum; the enormous price of that material precludes it from being employed on a practical scale.

1520.—*Show by a table the results after filtration through polarite.*

The following is a report on two samples of water which passed through polarite.

	Grains per Gallon.	
	Filtered through polarite.	Unfiltered.
Free Ammonia	A trace only.	·02632
Albd. Ammonia	·0360	·05096
Oxygen absorbed 15 min. at 80 ° F.	·0476	·1764
Nitrogen as Nitrates . . .	·17283	·18432
Colour	Pale yellow.	Deep orange yellow.
Odour	Odourless	Disagreeable.
Total Solid	25·76	31·36
Residue	Clean.	Dirty.
On Ignition	Darkened. Slight odour.	Darkd. much. Strong urinous odour.

These figures show a very remarkable degree of purification by filtration.

Thames water taken at Hampton Court has beeen purified by filtering through "polarite" at the rate of one thousand gallons per square yard in 24 hours, and the results obtained have been excellent.

1521.—*What is careferal? Is it a good filtering medium?*

A combination of calcined clay with saw-dust (charcoal) and a small quantity of iron.

It has good oxidising properties, and yields nothing to water which is favourable to organic life, but its lasting powers are inferior to spongy iron and magnetic oxide and carbide. It is losing its former popularity. Some experiments conducted at Netley by the late Professor DE CHAUMONT showed that for a time it acted as an efficient filtering and oxidising medium and then became less and less active, until it was useless.

1522.—*How may careferal be employed on a large scale and what are its effects as a filtering medium?*

Careferal should be employed, so that the whole bulk employed acts as filtering material. By using a large quantity of the material with a rapid delivery, a storage reservoir becomes unnecessary. The delivery can be regulated by screwing down or loosening a plate in the filter, so as to compress the material, or slacken the pressure as required.

1523.—*What form of material should be excluded from filtering media?*

All organic substances, such as sponge, flannel, cotton-wool, and tow, should not be used as filtering materials, either alone or combined with charcoal, etc. Any action they may possess is purely mechanical, and sooner or later they decompose and add impurity to the water.

1524.—*What may be said of sponge used as a filtering agent?*

It has a considerable effect in mechanically arresting suspended particles, but very little on dissolved matters. It soon clogs, and ought not to be used.

1525.—*Is sponge commonly used as a filtering medium?*

It is now not often used It merely removes suspended particles and soon clogs and becomes foul. Sponge filters require constant attention, and frequent cleaning and renewal. Asbestos is a much better material, and can easily be re-burnt. It acts only mechanically. [Strainers of sponge, or any material which cannot stand the action of fire, ought also to be given up. Asbestos forms an excellent strainer, and can be heated to redness, so as to destroy all organic matter, as often as required.]

1526.—*Why are sponge filters now considered dangerous to use?*

Because although they remove the suspended matter, organic and inorganic, they harbour the development of vegetable micro-organisms and soon become very foul.*

1527.—*How is a domestic filter to be cleaned?*

It may be taken to pieces every two or three months (according to the kind of water), air blown through it, and if it is in a block form, well brushed, then pour a solution of 20 or 30 grains of potassium permanganate to a quart of distilled water with 10 drops of strong sulphuric acid through it. After this, a solution of half-an-ounce of hydrochloric acid to four gallons of distilled water; then rinse thoroughly with plenty of distilled water, or good rain water. If the carbon is not in the block form, it may be boiled with Condy's fluid dried, and reburned, and then used again.

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* We have cut open a sponge of about 3 inches in diameter, that was in use for nine months and found that it was almost choked up with a semi-putrid slimy material, crowded with various forms of vegetable organisms, mould, and amœboid forms.

1528.—*Before a filter is used what should be done to it ?*

It is necessary before a filter is used that from 10 to 20 gallons of water should be passed through it, as all filters in the first instance yield a certain amount of foreign matter to the water. The most difficult to cleanse are the block carbon filters, but this may be accomplished by first carefully brushing the surface and pumping air in the reverse way, and afterwards allowing a mixture of dilute Condy's fluid with a little hydrochloric acid to pass through it, until it comes out a distinct pink colour. It is obvious that in the more complicated filters the cleansing can only be properly done by the maker, to whom it ought to be sent for the purpose.' When the filtering medium is loose charcoal, it may be cleansed in the same manner with Condy's fluid and acid, but the simplest plan in this case is to renew the carbon.

In both cases, after cleansing or renewal, it must be remembered that the clean water must be passed through the filter before it is again used. This cleansing process must be conducted at intervals, varying in accordance with the amount of impurity present in the water filtered, but the interval ought not to be longer than six months.

Every filter ought to be carefully inspected, and, at periodical times, the material ought to be removed and thoroughly cleansed, if that be possible ; and if it cannot be cleansed, a fresh supply ought to be substituted for it. The small expense incurred in this way is a wise outlay, in order to secure immunity from dangers that are otherwise certain to arise sooner or later.

In the case of spongy iron filters Condy's fluid and acid must not be used, but the material may be cleansed by burning it, although in this case also, the best plan is to renew it As spongy iron retains its filtering power longer than charcoal, this process need not, probably, be gone through oftener than every twelve months.

1529.—*Is sponge made use of as a filtering material ?*

Sponge occasionally forms part of the filtering material. They should be placed in boiling water for a few minutes every two days.

1530.—*What water-bottle is used by the British soldier ?*

The Italian water-bottle has been officially adopted in our army, but it is doubtful if it has any advantage except its convenient shape. It certainly imparts an unpleasant taste to the water at first, and presents difficulty in cleaning. Probably an iron bottle (coated by the Bower-Barff process), covered with leather, would be better. For convenience however nothing is better than an ordinary soda-water bottle covered with felt or leather slung over the shoulder.

1531.—*Give a brief resume of the methods employed for the removal of impurities from water?*

Organic matter by { Distillation, boiling, exposure to air, alum, permanganates, tannin, and by agitation with coke, etc.

Carbonate of lime by—Boiling, and addition of caustic lime.

Iron by—Boiling, lime, and, in part, by charcoal.

A combination of alum, line, and sodium carbonate removes the temporary, and even reduces the permanent hardness somewhat.

1532.—*Give a resume of the methods employed for the purification of water?*

Nature purifies water from vegetable and animal matter by decomposition and oxidation, aided by subsidence and filtration through porous strata, and also by evaporation and condensation.

Artificially, water may be purified by

(1) Distillation.

(2) By precipitating injurious matters by addition of various ingredients, by boiling, etc.

(3) By filtration.

1. *Distillation* will ensure pure water if properly carried out. The water should always be tried with a few drops of dilute nitric acid and silver nitrate before use; if no haze is produced the water may be safely taken.

   Precautions.—Aërate water; it will not keep good long; avoid lead in the apparatus, and take care foul water does not leak through.

2. (*a*) *Boiling* gets rid of calcium carbonate, hydrogen sulphide, and lessens organic matter and iron. Repeated boilings will destroy micro-organisms.

   (*b*) *Exposure* to air in divided currents, as through a sieve, removes hydrogen sulphide, offensive organic vapours, and perhaps dissolved organic matters.

   (*c*) *Aluminous salts* act well if calcium carbonate be present; a sulphate is formed, and with a bulky hydrated alum precipitate floating matters are carried down. To a gallon of water add six grains crystallized alum, adding first, should the water be soft, a little chloride of calcium and sodium carbonate. If BIRD's Patent Fluid be used (ter-sulphate of aluminium) twenty drops are added to a gallon.

   (*d*) *Lime* (CLARK's process) combines with carbonic acid and is precipitated with the calcium carbonate already in the water, carrying with it suspended matter and some dissolved organic matter and iron. It arrests micro-organisms. Does not affect sulphates and chlorides of calcium and magnesium. On a large scale ATKIN's modification is used.

(e) *Sodium carbonate* throws down sulphate of lime, leaving sodium sulphate in solution, and lead if present.

(f) *Potassium or sodium permanganate* removes the offensive odour of impure water kept in casks, etc.; of hydrogen sulphide; suspended matters are carried down by the manganic oxide precipitate. Gives a yellow tint to some waters from presence of finely-divided manganese peroxide; it is not injurious, but may be removed by addition of alum or by filtration. Add Condy's fluid, a teaspoonful at a time, to three or four gallons of water until a faint purple tint appears and remains for some hours. As a preliminary to the alum process it is useful.

(g) *Perchloride of iron* purifies turbid waters from clay, etc. To a gallon of water add two and a half grains of the solid perchloride.

(h) *Strychnos potatorum* is used in India; probably carries down suspended matter.

(i) Iron wire and magnetic oxide of iron are said to remove organic matter.

(j) Immersion or boiling in the water of certain vegetable bodies, especially such as contain *tannin*; tea, kino, bitter almonds, etc., have been used.*

CHAPTER XIV.

GASES IN WATER.

1533.—*Of what gases is water composed?*

Oxygen and hydrogen

1534.—*How may this be shown?*

It may be demonstrated, both by synthesis and analysis, that absolutely pure water is a true union and condensation of two gases, oxygen and hydrogen, in the proportion *by volume* of two of the latter and one of the former, and *by weight*, eight of oxygen and one of hydrogen. Its weight in the gaseous state relative to hydrogen is 9, and its chemical formula H_2O. (For other important points in connection with the relation of potable waters to gases *vide* Part I, Chapter I, p. 9 *et seq.*)

1535.—*What are the gases generally found in water?*

O, N, Co_2, and sometimes CH_4 (in marsh water) and H_2S.

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* Allen's *Aids to Sanitary Science.*

1536.—*What amounts of different gases should be contained in a good and wholesome water?*

Waters vary considerably in the proportions of their gaseous constituents. When freely exposed to the air, a good water which is not consuming oxygen by means of the organic matter, nitrites, or ferrous salts which it contains, ought to contain about 1¾ cubic inches of oxygen per gallon; and, to be palatable, to contain a fair proportion of carbonic aid gas in solution, so as to be brisk and not vapid in flavour. [There should be no odour in water; but the presence of a trace of sulphuretted hydrogen odour when freshly drawn *from a deep source* is not prohibitory of its use.]

1537.—*How are the gases of water estimated quantitatively?*

By means of the following appliances:—A mercurial trough, graduated glass tube filled with mercury and inserted in the trough, by a flask and connecting tube. The water placed in the flask is boiled for an hour and the gases thus evolved are collected in the graduated glass tube.

1538.—*By what apparatus and in what way may we ascertain the presence and test the nature and quantity of gases in water?*

So far as our knowledge extends at present, there seems to be but little information obtained by the determination of the amount of gases in water; but if it is decided to do so, we require a mercurial trough, a graduated tube-measure to be filled with mercury and inverted into the trough, a flask and a connecting tube with a bulb blown on it. The flask is filled with water and connected with the bulb-tube by an India-rubber tube, which is to be closed by a clamp. Some water is put into the bulb, and boiled; this is to expel air from the connecting tube; and when this is done, the end of the tube is put into the mercurial trough under the vessel filled with mercury, the clamp is removed from the India-rubber tube, and the water is cautiously boiled for an hour. The gases collect in the mercurial tube, and are measured (due regard being had to temperature and pressure, and the other corrections); the CO_2 is absorbed by potash, the oxygen by potassium pyrogallate, and the nitrogen is read as the residue.* If water contain much CO_2 bubbles of the gas form on the sides of the glass in which the water is placed.

1539.—*What apparatus are needed for the quantitative estimation of gases in water?*

Apparatus, etc.—A flask holding exactly, when fitted to the stopper, 700 decems (16 ounces); a glass bent tube with a bulb on it; one end is fitted into the stopper of the flask, the other is so bent as to pass below the mercury in a mercurial trough; a glass tube about a foot long, closed at one end, and graduated into 10ths of a cubic inch at that end; this tube must be filled with mercury and inverted in the mercurial trough; a bulbed pepette turned up at the end for introducing the solutions of caustic potash and of pyrogallic acid.

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* PARKES' *Practical Hygiene*, 7th Ed.

1540.—*How are carbonic acid gas, oxygen and nitrogen determined quantitively?*

By the following process:—

1. Fill the flask to the under-surface of the stopper.

2, Boil some water previously placed in the bulb to expel all the air in the tube.

3. Place the open end of the tube under the graduated tube standing in the mercury.

4. Now gently boil the water in the flask to liberate the gases.

5. Note the measure of the gases obtained.

6. Pass up into the measuring tube with the aid of pepette a solution of caustic potash (one part of dry potassium hydrate in two of water) equal to about $\frac{1}{40}$ to $\frac{1}{50}$ of the volume of the gases. When no further decrease of volume takes place read off as CO_2.

7. Now pass up as before a solution of pyrogallic acid (10 grains of acid in 5 or 6 decems of water).

8. Slightly shake the tube.

9. Read off the oxygen present as equal to further decrease in volume. The nitrogen will remain as a residual product, and the amount may thus be determined.

1541.—*What is* Dr. FRANKLAND'S *method of estimating the gases in water?*

It is a very ingenious method by which the gases are removed without employing heat. It is carried out by means of a modification of the Sprengel pump. The vacuum at the top of a barometer acts the part of an air-pump. This process may be carried out in such laboratories as are engaged in making water analyses, but the ordinary M.O.H. is not likely to be called upon to carry out this process.

1542.—*What is the relation of CO_2 to water which is from ordinary sources of water-supply?*

All waters contain it more or less, the CO_2 of the air being dissolved. Rain water dissolves comparatively small quantities of CO_2; 25 gallons of lake water seldom contain more than a quarter or half a pint of dissolved *carbonic acid gas*. This gas is very soluble in water, but as only four parts of it are contained in 10,000 parts of air, rain water contains but a small amount of it. Ordinary river and well waters contain considerable quantities of carbonic acid gas. This is accounted for by the fact that in the decomposition and oxidation of the organic matter which gains access to rivers and wells, carbonic acid is generated and dissolved. Water falling on the ground, finds its way to the animal and vegetable matter in the soil. The oxygen already dissolved in the water, oxidises the organic matter, and carbonic acid is given off in the process of decomposition. The water, deprived of its oxygen, absorbs a fresh supply from the air, and the formation of additional quantities of carbonic acid gas is repeated; so that the water becomes more and more saturated with it. Such is the main source of carbonic acid of water.

There is yet another source of carbonic gas in water that traverses the soil, *viz.*, the air of the soil itself. The air in the surface soil contains a considerable amount of carbonic acid gas (about 200 times as much as ordinary air, the proportion increasing as the depth increases). This carbonic acid gas has likewise been formed by organic decomposition. The water in its passage through the soil carries much of this carbonic acid with it, and this carbonic acid dissolves out any minerals met with that are soluble in a carbonic acid water. Chalk is thus dissolved, and the oxide of lime and soda are converted into carbonates.

It is the existence of this carbonic acid gas that gives good water the pleasant briskness, freshness and sharpness to the palate.

1543.—*How does carbonic acid gas affect the salts contained in natural water?*

The presence of CO_2 in water adds materially to the solvent power of the water upon many ingredients of the soil which are thus often introduced into the water—such as sulphate and carbonate of lime, chloride of sodium, magnesium salts, and certain organic matters of the surface.

4.—*How may the gases O, CO_2, and N be isolated?*

The O is separated by pyrogallate of potash; the CO_2 is absorbed by caustic potash, and the N is the residue.

1545.—*What are the hygienic relations of sulphuretted hydrogen to water?*

The presence of *sulphuretted hydrogen* is usually indicative of considerable deterioration of water. This gas is known by its odour. It is frequently found in water from superficial wells and in drying up tanks. It is formed in these by the deoxidation of sulphates of metals, and this deoxidation is effected by plants undergoing decay. The oxygen of the basic sulphates combines with the carbon of the organic matter to form carbonic acid, and the sulphate combines with hydrogen to form sulphuretted hydrogen.

If the gas is present in any quantity, it can be detected by the smell. Alkaline sulphides have, however, less smell. Both, even without smell, can be detected by salts of lead. A large quantity of water should be taken in an evaporating dish, and a little clear lead subacetate or acetate allowed to flow tranquilly over the surface. Black fibres of lead sulphide are formed. If lead acetate is mixed with solution of soda until the precipitate which at first forms is re-dissolved, a very delicate test-liquor is obtained. Solution of sodium nitro-prusside is also a delicate test, and gives a beautiful violet-purple colour. As it acts only on the alkaline sulphides, a little solution of soda or ammonia must also be added to detect the free hydrogen sulphide.

1546.—*What is the test for sulphides in water?*

Nitro-prusside of sodium gives a black precipitate with lead, but the absence of colour with nitro-prusside shows that the sulphuretted hydrogen is uncombined.

1547.—*Does the nitro-ferride of sodium differ from H_2S and sulphides?*

Yes: for it does not re-act upon uncombined H_2S. [Of a black hue with acetate of lead solution, but absence of colour with the nitro-ferride solution shows the H_2S to be uncombined.]

1548.—*What opinion should the presence of H_2S or alkaline sulphides in water elicit?*

The presence of *hydrogen sulphide* or *alkaline sulphides* ought to condemn the water.

CHAPTER XV.

MINERALS IN WATER.

1549.—*Under what headings may the impurities of water be conveniently considered?*

Firstly, water rendered impure by an excess of mineral substance; secondly, water rendered impure by the presence of vegetable matter; thirdly, water rendered impure by animal organic matter.

1550.—*Is the amount of mineral substances in water of much consequence?*

Of late years, an opinion has been expressed that the amount of the mineral substances is of little consequence. This can be true only in a limited sense; there are some mineral substances, such as sodium chloride or carbonate, or calcium carbonate, which, within certain limits, appear to do no harm. But in the case of other minerals, such as calcium and magnesium sulphates and chlorides, and calcium nitrate, there can be little doubt that their use is injurious to many persons.*

1551.—*Which of the mineral ingredients are least harmful?*

Many authorities hold that certain mineral ingredients, especially the alkaline carbonates (those of calcium, magnesium, sodium and potassium, and even the chlorides of these metals) may exist in large quantities without producing any deleterious effect on the animal economy; and we may state that a small excess of mineral constituents in water is of subordinate importance. On the other hand the majority of hygienists consider that very great excess of mineral impurities of any kind in water is capable of producing various forms of disease.

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* PARKES' *Practical Hygiene*, 7th Ed.

1552.—*What are the commonest salts of water?*

Carbonate of lime and magnesia, the latter held in solution by excess of CO_2.

1553.—*What mineral matters may be met with in water?*

These depend on the strata through which the water has passed. The chief are :—Chlorides, sulphides, carbonates, phosphates, nitrates, nitrites, and silicates.

1554.—*What bases are these salt radicals combined with?*

Sodium, potassium, lime, magnesium, alumina, and nitrates with iron, nitrites as Ph, yn, cu, as.

1555.—*How may we estimate the amount of carbonates?*

By determining the alkalinity and measuring the degree of hardness.

1556.—*What is the relation of calcareous salts in water?*

The *calcareous and magnesian salts* are the most frequent mineral matters met with, and of these the sulphates and carbonates are the chief to be dealt with.

Chalk (or carbonate of lime) is only soluble to the extent of two or three grains to the gallon in chemically pure water; but it is readily dissolved by the carbonic acid present in all natural waters. Ordinary limestone and marble are varieties of carbonate of lime. Gypsum, alabaster, and selenite are varieties of the *sulphate* of the same metal. The sulphate is more soluble than the carbonate, but is less diffused in the soil, and so is not met with in similar quantities. The amount of lime salts in water varies from one-third of a grain to the gallon in lakes surrounded by siliceous mountains, to 15 or 20 grains per gallon in many well waters, specially those in chalky districts.

1557.—*What suggestion has been made as to the use of lime salts in water?*

It has been supposed that the lime salts of water contribute to the formation of bone of animals, but it is usually in such small quantities as to have no material effect in this respect; and, further, Nature furnishes in ordinary food a much more convenient and suitable method of bone formation, than this. Even in places where large amounts of salts of lime are met with, no conspicuous influence is seen in the consumers—either the people become accustomed to the water, or the quantity of lime in it has no particular effect.

1558.—*What is the relation of magnesian salts to water?*

The *magnesian salts* are met with almost as commonly as the calcareous. Well water usually contains about 2½ or 3 grains to the gallon. It occurs as a carbonate with smaller quantities of the sulphate. These quantities have no effect on health. Some of the aperient mineral waters contain large quantities of sulphate of magnesia or Epsom salts. Excess of sulphate of lime and magnesia (10 to 20 grains to the gallon) may constitute an impurity.

1559.—*What is the test for lime in water? What is the result with varying quantities of lime?*

The addition of a solution of oxalate of ammonia to water containing lime gives a white precipitate—6 grains of lime to the gallon gives a turbidity only; with 16 grains there is a considerable precipitate.

It is important from a domestic point of view from its hardness, and from its effects on the alimentary canal and in washing clothes. [Glasgow saves £30,000 per annum by soft water. In the oxalate of ammonia test approximate estimate of the quantity of lime present is also possible. It may be present as carbonate (or temporary) or fixed (sulphates and chlorides). The carbonate is reduced by Clark's test and by boiling.]

1560.—*How may we estimate the quality of lime contained in water?*

By the soap test. Messrs. Boutron and Boudet have proposed, after determination of total hardness, to precipitate the lime by ammonium oxalate, and then to determine the hardness again. The difference will be owing to lime removed. The difficulty here is to add enough, and not too much, of ammonium oxalate, which itself in excess gives hardness.

The best way to perform this process is to have a perfectly concentrated clear solution of ammonium oxalate, and to add to 50 C.C. of water 1 drop for every 4 measures of soap solution used; then in other bottles, to add respectively, 1, 2 and 3 drops more. Then determine hardness of all the bottles, and select the result which gives the least hardness. In this way we can hit on the bottle which contains enough, but not too much ammonium oxalate. The water need not be filtered, but it should be allowed to stand at least for three or four hours or, better still, twenty-four hours, before the hardness is taken.

1561.—*How is the determination of lime by weight carried out?*

It may be desired to determine the lime by weight, and the following processes can then be used:—Take a known quantity of water; add ammonium oxalate, and then enough ammonia to give an ammoniacal smell. Allow precipitate thoroughly to subside, and then wash by decantation, or by throwing the precipitate on a small filter of Swedish paper, the weight of the ash of which is known. Decantation is recommended. If a filter is used, wash precipitate on filter; dry;

scrape precipitate from filter, and place in a platinum crucible; burn filter to an ash, by holding it in a strong gas flame, and place it also in the crucible. Heat the crucible to gentle redness for fifteen minutes, moisten with a little water, and test with turmeric paper. If no reaction is given, the process is done. If the paper is browned (showing presence of caustic lime), recarbonate with ammonium carbonate, drive off excess of ammonia, dry, and weigh.

The substance weighed is calcium carbonate, multiply by ·56, and the result is lime.

MOHR's plan might also be used, viz., precipitation of the lime in an ammoniacal solution by standard oxalic acid, and then titration of the excess of the latter by permanganate.*

1562.—*What is* MOHR's *test for lime ?*

Precipation of the lime in an ammoniacal solution by standard oxalic acid, and then titration of the excess of the latter by permanganate.

1563.—*What is the method of estimating magnesia by weight ?*

Take the water from which the lime has been thrown down; evaporate to a small bulk; filter if there be turbidity, add solution of ammonia chloride and ammonia to slight excess, then add a solution of sodium phospate; stir with a glass rod; set aside for twelve hours; throw precipitate on a filter, carefully detaching it from the sides of the glass; wash with ammoniacal water; dry; incinerate in an intense heat; weigh, taking care to deduct the ash of the filter known previous to experiment. The substance is magnesium pyrophospate; multiply by 0·36 oz. to get the amount of magnesia, or by 0·21622 for magnesium alone.

1564.—*What limit would you place on magnesium salts ?*

A water which contains above 5 grains per gallon of magnesium salts is not good for a public supply, and should be condemned for that purpose if there is a choice of better supply.

1565.—*What is the test for magnesia ?* (

It is usually in such small quantity that we cannot get a result from testing in ordinary water. *To test for it* we must concentrate the water by boiling down; this precipitates the lime salts, and then NH_4Cl is added and a little solution $(NH_4)_2\ CO_3$ to make it alkaline, and then a little Na_2PO_4. It turns it white. This is put in test tube; after boiling add the above solutions and leave aside for 24 hours, and now examine the sides of the tubes and we find crystals of triple phosphates. Water containing any excess of magnesia is not good.

In a good water there should only be a slight haziness or none at all, on the addition of ammonia.

An excess of lime or magnesia is evidence of hardness.

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s' *Practical Hygiene*, 7th Ed

1566.—*What salts of silica may be found in water?*

Silicates of soda or alumina are occasionally found in water.

1567.—*What is the test for silicates in water?*

Half a litre of sample water is evaporated to dryness; the residue is acted upon by strong hydrochloric acid, and washed with boiling distilled water; then it is once more dried, ignited, treated with acid, and washed with boiling water. The final residue is silica, and may be weighed as such after drying.

1468.—*How may we determine the earthy and alkaline carbonates by* MOHR'S *process?*

This is a very elegant process and may be useful. The solutions required are: Standard solution of sulphuric acid, 1 C.C., of which saturates 5 mgms. of calcium carbonate, and a colouring solution, such as cochineal or phenolphthalein.

Process.—Take 100 C.C. of the water to examine, and add a drop or two of cochineal solution, which gives a carmine red colour. Then run in the stardard acid solution till the colour becomes yellow or brown-yellow. Read off the uumber of C.C. used and multiply by 5. The result is parts of earthy and alkaline carbonates per 100,000, stated as calcium carbonate.

1569.—*Give an example of the working of this test?*

100 C.C. of a sample of water, reddened with cochineal required 5·6 of standard solution to make it yellow:—then $5{\cdot}6 \times 5 = 28$ parts per 100,000 of earthy and alkaline carbonates. If the water be not alkaline to test paper, the result will represent calcium carbonate only. Should the latter be already known (through the hardness), the difference, if any, will represent sodium carbonate, and may be calculated out as such, 1 C.C.=5·3 mgms. of sodium carbonate.

1570.—*How may we estimate the amount of phosphoric acid of the phosphates in water?*

The incinerated total residue of the solids is to be treated with a few drops of nitric acid, and the silica rendered insoluble by evaporation to dryness. The residue is then taken up with a few drops of dilute nitric acid, some water is added, and the solution is filtered through a filter previously washed with dilute nitric acid. The filtrate, which should measure 3 C.C., is mixed with 3 C.C. of molybdate solution.

1571.—*What is the importance of phosphates in water?*

Phosphates are not of common occurrence except in minute traces. They are, for the most part, indicative of remote animal pollution, but need not condemn a water if the other indications are satisfactory.

Phosphates may be present in water where there is sewage pollution, but they seldom exist, except in the smallest traces; as phosphates, being acid salts, are incompatible with calcium carbonate.

The presence of these in any marked quantity will generally corroborate inferences as regards sewage contamination drawn from the other indications. [Phosphates cannot exist along with carbonate of lime in a clean water, they are incompatible in a drinking water, the mineral phosphates of lime being precipitated.]

1572.—*What mineral matters may be found in water ?*

An immense number of mineral and other inorganic substances are scattered through the crust of the earth, but some few are in great preponderance, viz., compounds of silicon, aluminum, calcium, iron, carbon, chlorine, phosphorus, potassium, and sodium. Particles of clay and marl are amorphous and are unaffected by acid. Particles of sand are recognised by their angular shape and by their not being affected by acids. Particles of chalk are amorphous and are readily dissolved by acid.

1573.—*How may we examine the water residue ?*

The unignited residue is best employed for this purpose. A small quantity of distilled water is placed in the basin, and the reaction of the liquid to red litmus paper noticed, when an alkaline reaction will betray the presence of alkalies (potash or soda generally as carbonate). A few drops of hydrochloric acid are then added when any effervescence indicates the presence of carbonates. The liquid may then be tried for sulphates, for lime, and for magnesia in the usual way.

1574.—*What is the influence of geological formation in rendering water sparkling, colourless, palatable, and wholesome by percolation ?*

The following water-bearing strata are given as the most efficient :—

1. Chalk.
2. Oolite.
3. Green sand.
4. Hastings sand.
5. New red and conglomerate sandstone.

1575.—*What proof have we of the extent to which water may dissolve out the mineral constituents of the soil ?*

The power of water to dissolve out mineral constituents from the soil and geological strata is well seen by scanning the *composition* of a few of the most popular *mineral waters.*

1576.—*What is the composition of Hunyadi Janos water ?*

16 ounces Troy of Hunyadi Janos (Hungary) contain :—

	Grains.		Grains.
Sulphate of magnesia .	122·8	Carbonate of lime .	7·16
„ of sodium .	122·1	Oxide of iron and alumina . .	·03
„ of potash .	·65		
Chloride of sodium .	9·98	Carbonic acid, free and combined . .	4·00
Bicarbonate of sodium.	6·11		

This is a bitter mineral aperient imported from Hungary (Buda-Pesth) used for constipation, and to aid aperient pills in their action.

1577.—*What is the composition of Carlsbad water?*

16 ounces contain:—

	Grains.		Grains.
Sulphate of soda .	19·96	Carbonate of magnesia	
Carbonate of soda .	9·06	,, of iron .	·03
Chloride of sodium.	8·72	Phosphate of alumina .	·21
Sulphate of potash.	·36	Silica . . .	·1
Carbonate of lime .	2·02		

Drunk for obstinate constipation, affections of liver, gout, rheumatism, and diabetes.

1578.—*What is the composition of Seltzer water?*

Seltzer in Nassau furnishes the well-known Seltzer water.

16 ounces contain:—

		Grains.
Bicarbonate of soda		9·77
Chloride of sodium . . ,		17·22
,, of potassium. . .		·28
Sulphate of soda		·26
Phosphate of soda		·26
Bicarbonate of lime		2·66
,, of magnesia . . .		2·55
,, of iron . .	Traces	
,, of manganese .		
Bromide of sodium . .		
Silica		·25

1579.—*What is the composition of Friedrichshall water?*

This is likewise a bitter water, used in diseases of the stomach, liver and urinary organs.

16 ounces contain:—

	Grains.		Grains.
Sulphate of soda .	46·51	Sulphate of potash .	1·52
,, of magnesia .	39·55	,, of lime .	10·34
Chloride of sodium .	61·10	Carbonate of lime .	·11
,, of magnesium.	30·25	,, of magnesia.	1·16
Bromide of magnesium .	·37	,, of silica .	·33

1580.—*What is the nature and origin cf deposits in boilers?*

When water containing a quantity of earthy salts is concentrated, not only is the carbonate of lime deposited in the way just described, but as the solution becomes more and more concentrated the other earthy constituents present are more or less completely thrown down. Thus we find that a large deposit occurs in steam boilers in which ordinary water is used, and much inconvenience frequently arises from this source, especially when the deposit assumes a compact form, from the slowness of its deposition. Many schemes, both chemical and mechanical, have been proposed to obviate this inconvenience; but the treatment must vary with the character of the water. If the incrustation cannot by any means be *prevented*, a plan frequently adopted is to introduce some light powdered substance into the boiler with the water. This acts mechanically, by keeping up the free generation of steam; and the water being thus kept in constant and violent motion. Another method is the addition of chloride of ammonium to the water in the boiler. A conversion of the carbonates of lime and magnesia into soluble chlorides is the result, while the carbonic acid passes off with the ammonia as carbonate in the steam. The great objection to this method is, that carbonate of ammonia acts on brass or copper fittings, and this has precluded the employment of the process, except under special conditions.*

CHAPTER XVI.

EXAMINATION OF WATER.

PHYSICAL EXAMINATION.

1581.—*What is the object of undertaking a complete examination of water ?*

To enable the analyst to form an accurate opinion as to the wholesomeness or otherwise of a drinking water it can only be arrived at after subjecting a sample of it to a complete examination. This consists in an investigation into the physical characters of the water, a chemical analysis (both qualitative and quantitative) and a microscopical examination.

1582.—*Give the details of circular from the Medical Department of the Local Government Board relative to the collection and transmission of samples of water for examination ?*

1. In collecting samples for chemical analysis, the following instructions are to be followed :—

(*a*) Winchester quart bottles, stoppered, are to be used: the bottles must be thoroughly cleaned, and new bottles are to be preferred.

(*b*) Two bottles of each sample are to be collected.

(*c*) The bottles are to be rinsed out twice on the spot with the water which is to be collected.

(*d*) The bottles are to be filled, if possible, by dipping beneath the surface, and to be filled within an inch of the stoppers; and the stoppers are to be tied over with leather, bladder, on India-rubber, and the strings to be sealed against the bottle.

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*HUSBAND's *Medical Police.*

2. In collecting samples for fermentation-experiments, the prepared vacuum tubes (which are five inches long and half an inch wide) must be used according to the following directions:—

(*a*) If the water is in a cistern or other receptacle, plunge the fine end of the tube deeply in the water, and (with finger and thumb or with nippers) break off well below the surface the point of the tube so as to allow the influx of the water: not withdrawing the end of the tube till the water has ceased to enter it.

(*b*) If the water is in a stream where collecting it as above would be difficult, collect it first in a clean cup, which has been rinsed with boiling water, and into which the stream should then be allowed to flow freely for some minutes; and next fill the tube from this cup as from any ordinary receptacle.

(*c*) If the water is in a well, the tube must be filled from the bucket, immediately after it is raised, and with care previously taken that the bucket (outside and inside) is quite clean.

(*d*) In cases which allow the natural sediment of the water to be collected, it will be desirable to fill two tubes from each water; one, in such a way that it may contain water from near the surface; the other, in such a way that it may contain the natural sediment from near (but not quite at) the bottom.

(*e*) In each case, immediately after the tube is filled, seal the end of it in a flame.

3. In collecting samples, whether for chemical analysis or for fermentation-experiments, the time and place of collection of each sample are always to be noted by the collector; and each bottle or tube is to bear either a copy of this note, or else some distinguishing name or number by which the sample can afterwards be identified.

4. Samples for examination are, in all cases, to be forwarded to the office without delay, accompanied by the name of the sender.

1583.—*In acquiring samples of water for examination what precautions are to be taken?*

Collect the water in a scrupulously clean glass-stoppered bottle, of about half a gallon capacity. The water should be kept in a cool, dark locality, and the examination should be carried out as soon as possible. In collecting the water from a tank or well, the surface impurities should be avoided by immersing the bottle, and removing the stopper, under water. The middle of the stream, river or tank, should be chosen, avoiding the intake of feeding channels. If from a public tap, or hydrant, the tap should be opened for a few seconds before filling the bottle. Make a note of the place, time and period of the year. Remember to wash the bottle out two or three times with some of the water to be examined, and do not quite fill it.

1584.—*What are the chief points regarding which the analyst is concerned?*

Date and hour of collecting water; its source—from a well, tank, stream or river.

If from a *well*, the nature of the soil and geological strata in which the well is sunk, the depth of the well, and whether it is near or remote from well-privies, cesspits or drains.

If from a *tank*, the part of it from which the water was removed, and the nature of the various contaminating agencies (if any) at work.

If from a stream or river, the relation of the position from which the sample was taken to the banks.

The analyst should also be made acquainted with any special reason there may be for making an analysis.

A little practice in the physical and chemical examination of water would soon enable us to form a fair opinion of samples of water, or at least familiarise us with the chief characters by which waters may be distinguished as grossly contaminated.

1585.—*In despatching water to the Analytical Chemist is it important to provide full information regarding Samples that care should be taken that no chances of contamination exist?*

Trained analysts exercise the utmost caution in expressing their opinions as to the quality of waters analysed by them, for they are conscious of the importance of their decision. It is but fair then, that in sending samples for analysis, such samples should be accompanied by as much information about the water as it is in our power to give. In point of fact many analysts will not express judgment on a water until they are furnished with this information. It is often a waste of time and labour to send six or eight bottles of water marked A, B, C, &c., without any further reference to the water sent.

1586.—*What evidence have we indicating the importance of inquiry into the past history of potable water?*

1. The rapidity with which different kinds of organic matter oxidise is not uniform: and of all the varieties, that which is organised and living offers by far the greatest resistance to oxidation. Now, the researches of Chauveau, Pasteur, Koch, Burdon-Sanderson, Klein, and others leave no room for doubt that the specific poisons of the so-called zymotic diseases consist of organised and living organic matter; and it is now certain that water is the medium through which some at least of these diseases are propagated. It is evident, therefore, that an amount of exposure to oxidising influences which may resolve the dead organic matter present in water into innocuous mineral compounds may, and probably will,

fail to affect those constituents which are endowed with life. Hence, much organic nitrogen means great risk of the presence of these zymotic poisons. The investigations into the cause of the outbreak of typhoid fever at Lausen, in Switzerland, and at Caterham and Redhill, afford a remarkable confirmation of the virulence of these poisons.

2. The oxidising influences to which organic matter in water is subjected vary in activity at different times, and it by no means follows that because at the time of the analysis the offensive matter has already been converted into innocuous mineral compounds, the change would therefore be equally complete under future altered conditions as regards temperature, exposure to air or vegetation, and comparative volume of pure water. So long as there is a chance of the purifying effect on the water decreasing, there is always a risk of the harmless "inorganic nitrogen" becoming the "organic nitrogen" of some putrescent and perhaps contagious matter.

1587.—*How much water is required for a complete examination?*

From $\frac{1}{2}$ to 1 gallon. [For a complete qualitative and quantitative examination a gallon is needed. For an ordinary examination half a gallon, though a much smaller quantity may be made sufficient to carry out the more important examinations requisite].

1588.—*What quantities of water are requisite for the examination under different forms of pollution?*

The following are the quantities of water necessary for such analyses as are required for sanitary purposes:—

Sewage. Polluted rivers and streams. Shallow well waters.	One Winchester quart.
Deep wells. Ordinary unpolluted rivers, streams and springs.	Two Winchester quarts.
Lakes and tarns Mountain springs and streams.	Three Winchester quarts.

1589.—*What is the best form of bottle for the collection of samples of water?*

Best bottle is the stoppered glass bottle known as the Winchester quart.

1590.—*To ensure the perfect cleanliness of the collecting bottle how should it be treated?*

First thoroughly rinse out in caustic alkaloid, then wash in hot water, and then treat with strong sulphuric acid, and fill with water again.

1591.—*What arrangements should be made in regard to collecting samples of water by the Health Officer and Inspector of Nuisances?*

The Medical Officer of health will find it very convenient to have a basket containing two or more clear glass-stoppered bottles placed under the charge of the Sanitary Inspector of the district. The basket should be provided with a padlock fitted with two keys, one of which should be in the possession of the Medical Officer of health and the other retained by the Inspector. Before forwarding the bottles, the Inspector should affix a label to each, containing the date and a distinctive number, or certain particulars with regard to the source of the water and why it is suspected. For ordinary analysis pint stoppered bottles will be found to be large enough, because, should a greater quantity be required at any time, two bottles can be used instead of one.

1592.—*Can a complete analytical examination of water be carried out by an ordinary medical officer?*

Not as a rule. An exhaustive analysis of any given sample of water can only be conducted in the laboratory and by a professed chemist, it would be out of place here to attempt to describe any other than easily applied methods for arriving at a reliable estimate of the qualities of a water and whether it may safely be used.

1593.—*Enumerate the apparatus required for the analysis of water?*

A balance to carry 100 grms. in each pan and to turn when loaded with half a milligrm.; a box of gramme weights, 1 platinum dish to contain 100 C.C. of water (about £2 7s.) a copper water bath with holes cut in it for the reception of the dishes, a set of glass and porcelain dishes; a porcelain slab; graduated flasks, either 100 C.C., 500 C.C., and 1 litre, or if preferred, 70 C.C. and 700 C.C. These flasks have a circular mark scratched on the neck, and contain the exact quantity when they are filled up to this mark. Two or three retorts, each capacious enough to hold a litre, the retorts should be tubulated and stoppered; a copper air bath, with a Page's regulator and thermometer; at least two burettes, with stand; a Liebeg's condenser, with adapter and stand; Nesslerising cylinders; retort holder with universal joint clips; triangular stands; asbestos mill-board; wire gauze; triangles made of wire, covered with pieces of tobacco pipe for the support of platinum or porcelain dishes during ignition; one or two pairs of crucible tongs; filter paper; corks; cork-borers; distilled water; pure sulphuric acid; pure hydrochloric acid; pure potash; potassic permanganate; silver nitrate; potassic iodide; potassic chromate; sulphate of copper; zinc foil; ammonic chloride; calcic carbonate; mercuric chloride; pure sodic chloride; sodic hyposulphite; etc.

1594.—*When can a reliable opinion as to the quality of a water be expressed ?*

An accurate opinion as to the wholesomeness or otherwise of a drinking water can only be arrived at after subjecting a sample of it to a complete examination. This consists in an investigation into the physical characters of the water, a chemical analysis (both qualitative and quantitative) and a microscopical examination.

1595.—*Write a scheme for a complete investigation into the quality of a sample of water.*

The scheme of such an examination may be represented as follows :—

A. PHYSICAL ...
- 1. Colour.
- 2. Clearness.
- 3. Sediment.
- 4. Lustre.
- 5. Taste.
- 6. Smell.

B. CHEMICAL.

(*a*) *Qualitative.*

- Chlorine.
- Lime.
- Magnesia.
- Sulphuric acid as sulphates.
- Phosphoric acid as phosphates.
- Nitric acid as nitrates.
- Nitrous acid as nitrites.
- Ammonia.
- Iron.
- Lead.
- Copper.
- Zinc.
- Sulphuretted hydrogen.
- Alkaline sulphides.

(*b*) *Quantitative.*

Chlorine.

Hardness
- Total.
- Temporary.
- Permanent.

Solids ...
- Total.
- Volatile.
- Fixed

Oxidisable Organic matter.

Ammonia ...
- Free or saline.
- Albuminoid.

Nitric acid.
Nitrous acid.

C. MICROSCOPICAL EXAMINATION.

D. BIOLOGICAL INVESTIGATION.

1596.—*Does the foregoing scheme embrace a full examination of water ?*

By no means ; for after all these processes have been carried out there is a further requirement,—that of an endeavour to cultivate any microscopical vegetable germs that may be present, and ascertain their nature. This is termed the morphological or *biological* *examination.* When this also has been accomplished, we are placed in a position to give the most reliable and trustworthy opinion as to the quality of a given sample of water. To carry out these processes with accuracy demands that the analyst shall have had a sound chemical training, and that he be familiar with the use of microscopes of high power. Hence the uselessness of lay persons undertaking anything but a physical and simple chemical examination of water. On the other hand in the vast majority of cases, a sufficiently trustworthy opinion can be formed as to the quality of a water, after a physical and chemical examination of it has been made by a competent person.

1597.—*Does an examination of water, conducted according to the foregoing scheme justify us in expressing an opinion as to its quality ?*

It does; if the description of the locality together with the results of physical and chemical characters of water be given and all these prove satisfactory, we may declare a water to be useful ; if otherwise, the water should be regarded as dangerous.

1598.—*What, according to* FRANKLAND, *constitutes a complete quantitative examination of water ?*

Such an exhaustive examination includes :—

1. The extraction and separate volumetric measurement of the dissolved gases.
2. The separate determination of the weight of each constituent of the saline matters in solution.
3. The determination of the two chief elements of the organic matters in solution.
4. The separation of the suspended matters, if any, and the determination of their total weight when dry.
5. The separation and determination of each mineral constituent of the suspended matters.
6. The separation and determination, as far as possible, of each organic constituent of the suspended matters.

1599.—*What points may be ascertained from a physical examination of water ?*

Much may be learnt from a simple physical examination, and all but experts are obliged to rely on the results of such an examination. From a physical examination of water we ascertain the *colour, clearness, lustre, taste* and *smell* (if any), and the existence or not of any visible *suspended matter* or *sediment.*

1600.—*How may we conduct a preliminary examination of water ?*

By filling a flask of white glass with the water to be examined, and comparing its colour with that of distilled water contained in a similar flask. Next warm some of the water in a test-tube; shake it, and observe if the water possesses any peculiarities. Note its physical characters, as to smell, taste, colour, sediment (after standing), suspended matter, etc.

1601.—*What is the first step in the physical examination of water?*

A portion of the sample collected should be poured, after shaking the bottle, into a good-sized clean glass flask. If the flask is then held in front of a dark-coloured surface, with a good light falling on the side or from above, any suspended impurities will become visible, but care should be taken to discriminate between them and air bubbles.

1602.—*How do we investigate the nature of the sediment in water?*

To find out the amount and nature of the sediment, the water is to be allowed to stand some time. The general characters of the sediment may now be investigated. It may be examined microscopically, and in this way its exact nature be discovered. It may also be subjected to the *biological test.*

1603.—*Give a rough method of estimating the suspended matters in water?*

Pass a known quantity of water through filter paper previously washed in distilled water. The increase in the weight of the filter paper gives the quantity of total suspended matter in the known volume of the water. Burn the paper, and weigh the ash; then burn an unused filter paper previously ascertained to be precisely similar to that used and also weigh its ash; the quantity of ash in excess of that contained in the unused filter gives the amount of suspended organic matter in the water.

1604.—*How do we proceed to examine the sediment of water, when it is present in very small amounts?*

When a water is much discoloured from impurities, there is no difficulty in obtaining enough of the sedimentary matter for microscopical examination. But sometimes the sediment is so small in amount that several slides may have to be examined before anything is met with. When this is the case, a long narrow cylindrical glass, thoroughly cleaned, should be filled with the water to be examined, allowed to stand for 24 hours, and then the water to within ¼″ from the bottom should be siphoned off, and preparations made from it in the ordinary way.

1605.—*How may we observe the odour of the water?*

A portion of it should be poured into a wide-mouthed flask, making it about one-third full and then shaking it well. If the smell is unpleasant, the water is unfit to drink. Should no smell be detected, the flask should be heated, and the water again shaken, and if there is still no smell a little caustic polish should be added to the warm water. Any unpleasant odour which may now be given off indicates with certainty that the water contains organic impurities.

A smell is usually due to putrefaction, in which the evolution of sulphuretted hydrogen and ammonia compounds is taking place. Any smell in water is best brought out by heating it to about 100° Fahr., and adding a little caustic soda to the water.

1606.—*What effect has the warming of water as to its odour, if any, be present?*

It renders any peculiarity as to smell more perceptible.

1607.—*What may be stated with regard to the lustre of water?*

With regard to *lustre*, the technical terms in use are, *adamantine* and *vitreous* or dull, words which sufficiently express their meaning. The lustre of a drinking water depends on the gases, oxygen and carbonic acid dissolved in it. Good water has an adamantine lustre; in other cases it is dull or vitreous.

1608.—*How is the turbidity of water ascertained?*

Turbidity is ascertained by holding a flask of water (say, of a litre or quart size) between the eye and a source of light, having at the same time some dark object, such as a window bar, in the field of vision. It will depend on the purpose of an analysis whether the solid matter causing the turbidity is to be filtered off before the commencement of the analysis, or is to be shaken up and treated as part of the water. There should be no turbidity in a water, or, if any, this should be due to vegetable or mineral matters and easily removable.

In waters turbid from exceptional causes, and rendered so by rust, chalk, or other innocuous mineral matter which would naturally settle down, or be separated if a filter were used, the suspended matter may be filtered off and disregarded. In the case of sewage, liquid refuse from factories, or polluted water containing solid organic particles, the liquid should be passed through a proper filter paper or of double Swedish paper, and the residue (dried at 100° C.) weighed. The increase in weight gives the "total suspended matter;" and the weight of residue, after ignition, treatment with solution of ammonic carbonate, and drying at 150° C. (less weight of filter ash), gives the "mineral suspended matter." The "organic suspended matter" is represented by the difference between the two weights.

1609.—*What are the causes of turbidity in water?*

Mineral matters of various hues in the soil, through or over which water percolates or flows, are the more usual cause of discoloration and turbidity. Peroxide of iron, in particular, may be mentioned as the source of the brown cloudy appearance of water from the blue clay, as also frequently of the brown colour of pools in bog-lands, though this more usually arises from organic matter passing into decay. In the coarser sediment under such circumstances, the microscopic forms of animal and vegetable life are likely to be abundant, (*viz.*, Rotifera, Infusoria, Rhizopods, Oscillatoria, Desmids and Diatoms). In ferruginous bog-water also the twin spiral filaments of *Didymohelix*, invested with a yellowish-brown gelatinous matter, and *Liptothrix ochrea*, a rather ill-defined myeloid structure, may add to the general effect. By reflected light, moreover, the fine amber tint of the *Diatomaceæ*, floating or resting, is quite brown, some of the heterogeneous materials usually occurring in bog-water.

1610.—*How may we examine water as to clearness?*

This is best done by filling a good sized flask, 1,200—1,500 C.C. capacity, with the water The flask is now to be held in front of a dark-coloured or black wall, a strong light falling on the flask from one side or from above. Care must be taken not to confound minute bubbles of air with suspended matter. Any water that is not clear and transparent, cannot be reckoned as one of the first order. Dissolved or finely-suspended particles of colouring matter will reduce the natural clearness of pure water, as will also finely-divided and suspended mineral matters. Most of such suspended matters subside on allowing the water to stand, but fine particles of calcareous salts, and of mica, etc., may not subside.

1611.—*In investigating the colour of water how do we proceed and what conclusions may we arrive at?*

For this we use narrow cylindrical, clear glass vessels, about 2 feet in height. We fill one with the water under examination, and the other with distilled water for comparison. We place these in a good light, on a white slab, or on some white printed paper, and see if we can read the print below.

As a rule, water should have no colour, except a bluish tint when viewed through a depth of two or more feet. Waters are often slightly *greenish*, due to cellular *algæ*, and such waters are not considered impure on this account. Waters of a *yellowish* or a *brownish* colour are to be looked upon with suspicion. A *yellowish* hue is often due to peat, in which case the water, although unpleasant, is innocuous and may be used. A brownish or yellowish hue may be due to iron; it then has a chalybeate taste; even one-fifth of a grain to the gallon gives this taste. A similar colour may be due to sewage contamination.

The colour and degree of turbidity are important indications. Perfectly pure water has a bluish tint, and permits of the bottom of the vessel being distinctly seen even at a depth of several feet. Turbidity, usually described as very slight, slight, turbid, and very turbid (VST., STT., and VT.), obscures it, and a blue-green, green, yellow-green, yellow, yellow-brown, or brown hue, similarly described by initial letters, indicates less or more organic pollution. Some chemists mark the depth of each tint by adding the numerals 0, 1, 2, and 3, and Messrs. CROOKES, ODLING, and TIDY employ two wedge-shaped hollow glass vessels filled, one with a brown and the other with a blue solution, and made to slide across one another in front of a circular aperture in a sheet of metal, by which means any desired combination of brown or blue can be obtained. Each prism is graduated along its length from 1 to 50, these figures indicating the thickness of the solution at that particular point in millimeters.

1612.—*Does the sense of taste help us in testing the quality of water?*

The taste of a drinking water depends, as a rule, on the gases dissolved in it, and not on the mineral salts it contains. The taste should be agreeable and as a rule not distinctive of any special substance. It may be said that any water in which the mineral matters in solution are recognised by the palate is unfit to drink. An ordinary drinking water contains from 20 to 25 grains of common salt to the gallon. It requires about three times this quantity to be recognisable by the sense of taste.

Taste is an uncertain indication. Any badly tasting water should be rejected or purified before use. Suspended animal organic matters often give a peculiar taste, so also vegetable matters in stagnant waters. Some growing plants, as *lemnia* and *pistia*, give a bitter taste; but most growing plants have no taste. Dissolved animal matter is frequently quite tasteless. As regards dissolved mineral matters, taste is of little use, and differs much in different persons. On an average—

Sodium chloride	is tasted	when it reaches	75	grains	per gallon.
Potassium „	„	„	20	„	„
Magnesium „	„	„	50 to 55	„	„
Calcium sulphate	„	„	25 to 30	„	„
„ carbonate	„	„	10 to 12	„	„
„ nitrate	„	„	15 to 20	„	„
Sodium carbonate	„	„	60 to 65	„	„
Iron	„	„	0·2	„	„

Iron is thus the only substance which can be tasted in very small quantities. A permanently hard water has sometimes a peculiar *fade*, or slightly saline taste, if the total salts amount to 35 or 40 grains per gallon, and the calcium sulphate amounts to 6 or 8 grains. The taste of good drinking water is due entirely to the dissolved gases; water nearly free from carbonic acid hardness, such as distilled water, is not so pleasant as the brisk well-carbonated waters; it may be called flat, but it is difficult to define the kind of taste or absence of it.*

With regard to taste, it is sufficient to say that a badly-tasting water should be condemned for drinking purposes. Many waters, however, which are largely impregnated with dissolved animal impurities may be quite palatable.

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* PARKES' *Practical Hygiene*, 7th Ed.

1613.—*What may be said as regards the keeping power of a good water?*

A good drinking water when kept in a bottle loosely plugged with sterilised cotton wool, should not become putrid, nor deposit anything beyond a trifling amount of chalky matter.

1614.—*Can a reliable opinion be expressed from a physical and chemical examination of water?*

In the majority of cases, a sufficiently trustworthy opinion can be formed as to the quality of a water, after a chemical and physical examination of it has been made. Further, much may be learnt from a simple physical examination, and all but experts are obliged to rely on the results of such an examination.

1615.—*What may be stated of a water which gives negative results in its physical examination?*

We may ordinarily regard such a water as of good quality. If we are at all doubtful as to its characters, we should have it subjected to both a qualitative and quantitative chemical examination. We would repeat however that the senses are unreliable judges in estimating the wholesomeness of a water.

Although the *physical characters* give only an imperfect idea of the value of a water, they are yet important when no further examination can be made. If a water be colourless, clear, free from suspended matter, of a brilliant (or adamantine) lustre, devoid of smell or taste, except such as is recognised to be the characteristic of good potable water, we shall in the large majority of cases be justified in pronouncing it a good and wholesome water; whilst, according as it deviates from these characters, we shall be proportionately justified in regarding it with suspicion. Suspended matter is probably the most dangerous, but it may well be that minute particles, the "resting spores" of disease-causing organisms, may exist without revealing themselves by any visible turbidity (or even to a cursory microscopic examination).

Altogether, the physical examination of water is of a negative character, and although it may impart some useful information, it cannot be relied upon in arriving at a sound conclusion as regards the good or bad qualities of any given sample.

1616.—*How may we classify waters?*

Into:—1. *Pure*, a water of first quality, usable without any further preparation.

2. *Usable*, or becoming so by filtration, is not a first clear water as it fails in certain points.

3. *Suspicious*, in which although the water may not be dangerous it should be used cautiously, and before using should be thoroughly examined chemically and microscopically.

4. *Impure*, which should be absolutely condemned.

1617.—*Give a table indicating the chief physical characters of the waters according to the foregoing classification.*

Character or constituent.	1. Pure and wholesome water.	2. Usable water.	3. Suspicious water.	4. Impure water.	REMARKS.
Clearness, lustre, and aëration.	Transparent, sparkling and well aerated.	Transparent, sparkling and well aerated.	Turbid ...	Subsoil and not easily purified by coarse filtration.	Turbidity due to very fine aërial matter is sometimes associated with pure waters; thus minutely-divided calcium sulphate will not subside in distilled water.
Suspended matter.	Detectable by the eye.	Absent or easily separable by coarse filtration or subsidence.	Considerable ..	Large ...	...
Colour ...	Colourless .	Colourless or slightly greenish.	Yellowish ...	Distinctly yellow or any marked colour.	When the impurity is mostly vegetable, the colour may be very marked in good, or at least usable, water.
Taste ...	Palatable ...	Any marked taste.	Any marked taste.	..	...
Smell ...	None ...	None ...	..	...	...

1618.—*Give a sketch of the various constituents of drinking water?*

A.—Gaseous. *B.*—Dissolved solids. *C.*—Suspended matter.

A.—Gaseous constituents:—

1. *Useful gases.*

$$\left.\begin{array}{c} CO_2 \\ O \\ N \end{array}\right\} \text{of air.}$$

2. *Noxious gases.*

$$\left.\begin{array}{l} H_2S \\ (NH_4)_2S \\ NH_3 \end{array}\right\} \text{products of decomposition.}$$

B.—Dissolved Solids:—

Mineral: 1.—Salts of Calcium Magnesium.

2. *Organic*:

$$\left.\begin{array}{l} HNO_3 \\ HNO_2 \\ NH_4 \text{ Salts} \end{array}\right\} \text{products of organic oxidation.}$$

C.—Suspended matter:—

Organic: 1. Capable of putrescence or putrefaction.

2. Incapable of putrescence or putrefaction as urea, fatty acids, etc.

1619.—*Whence are the present natural waters obtained?*

The purest water which can be collected from drainage, is found in the barren moorland districts of the primary geological formations or of the sandstone rocks.

1620.—*How may we classify the origin of the impurities of the water?*

The origin of the impurities in water may be conveniently referred to four heads, viz.:—(1) substances derived from the source; (2) substance, added during the flow of the water in rivers, canals, aqueducts, or other conduits; (3) impurities caused by storage in reservoirs or tanks; and (4) substances added during distribution from reservoirs either in pipes or water barrels, or in house cisterns.[*]

CHAPTER XVII.

EXAMINATION OF WATER—*continued.*

QUALITATIVE CHEMICAL EXAMINATION OF WATER.

1621.—*What is the reaction of water?*

Nearly all waters are alkaline, and strike therefore a yellow colour with methyl orange, a dark red with cochineal. If acid, the colour with methyl orange is reddish orange, with cochineal of a yellow tint.

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[*] *Practical Hygiene*, 7th Ed.

1622.—*How is the reaction of water determined?*

This is determined by litmus and turmeric papers—water of acid reaction giving a red colour to blue litmus paper, alkaline water turning turmeric paper brown.

Water is usually either faintly alkaline or neutral in reaction. If there be acidity which disappers on boiling, it is due to carbonic acid gas. On the other hand, if the alkalinity disappears on boiling, it is due to ammonia. Permanent alkalinity is due to carbonate of soda. [Rain water and peaty waters are generally slightly acid in reaction. If it be desired to determine the extent of acidity of a water, this may be done by placing half a litre in a flask provided with a reflux condenser, and boiling the water vigorously for fifteen minutes or so, to expel carbon deoxide. The acidity is then determined by running in decinormal soda solution from a burette, using phenolphthalein as an indicator. Some analysts prefer to use methylorange to determine the point of neutrality. By operating on two separate half litres, using the two indicators respectively, a distinction may be made between mineral and organic acids.]

1623.—*What is the test for chlorine in water?*

The presence of chlorine is determined by acidifying water with a little dilute nitric acid, and adding a few drops of nitrate of silver solution. One grain to the gallon gives a haze; four grains give a distinct turbidity, ten grains a slight, and twenty grains a considerable precipitate.

1624.—*What is the test for nitrous dcid as nitrates in water?*

A solution of pure iodide of potassium, followed by some freshly prepared starch solution is added to the water, and this again followed by some sulphuric acid. A blue colour is developed. The colour should be immediate. Make a comparative experiment with distilled water.

1625.—*What is the ordinary qualitative test for nitric acid as nitrates in water?*

Mix a little of the water with twice its bulk of pure sulphuric acid. This sets free the nitric acid from its combinations; then add a few drops of the solution of brucine—a pink and yellow zone occurs at the junction of the water and acid. The sulphuric acid should be poured down the test tube gently, so as to form a layer beneath the mixed water and brucine solution. Half a grain of nitric acid to a gallon gives a marked pink and yellow zone. This is a very delicate test. Another method is to evaporate down two cubic centimetres of water to dryness, add a drop of pure sulphuric acid and a minute crystal of brucine. The same reaction takes place, and by it ·01 of a grain to the gallon can be easily detected. In the above test, if a solution of pyrogallic acid be employed instead of that of brucine, a pink zone, turning purple, will be observed.

1626.—*What is the relation of nitrates to water?*

Almost all waters contain a certain amount of either nitrate of sodium (cubic nitre), or nitrate of potassium (saltpetre), or nitrate of lime (calcareous nitre). Nitre is an oxidised product of decomposed dead animal and vegetable matter. In the quantities in which it is usually found, it is not only not harmful, but probably beneficial to man and animals using the water, and it forms part of the food of all plants, the juices of which invariably contain some of it.

1627.—*What is the test for H_2S in water?*

A solution of a salt of lead added to the water gives a black precipitate. When the water is heated, the smell of sulphuretted hydrogen may be perceived.

1628.—*What is the best test for the presence of sulphides in water?*

Nitro-prusside of sodium gives a black precipitate with lead, but the absence of colour with nitro-prusside shows that the sulphuretted hydrogen is uncombined.

1629.—*What is the test for the presence of sulphuric acid as sulphates in water?*

The test for sulphuric acid in water is carried out by adding some dilute hydrochloric acid and chloride of barium · 1½ grains of a sulphate give no precipitate until after standing, 3 grains give an immediate haze, and after a time a slight precipitate. Dilute nitric acid and nitrate of barium may be used as reagents for the same purpose.

1630.—*How may we estimate the amount of sulphuric acid by weight?*

Take a known quantity of the water (500 to 1000 C.C.), acidify with hydrochloric acid and evaporate, but not so far as to run any risk of throwing down sulphate of calcium, filter; and then add chloride of barium; allow to stand, and wash the precipitate by decantation; dry; weigh; multiply precipitate by ·34305 to get the amount of sulphuric anhydride (SO_3) or by ·411, if it is wished to calculate it as SO_4.

1631.—*How may we estimate the sulphuric acid by the soap test?*

This plan was proposed by BOUTRON and BOUDET, and is briefly as follows:—The hardness of the water being known, 50 C.C. of the standard barytic solution (·26 grammes per litre) are added to 50 C.C. of water, and the mixture is allowed to stand for twenty-four hours. The hardness (supposing no SO_4 were present) would be exactly equal to the original hardness of the water and of the barytic solution combined. But SO_4 being present, barium sulphate is precipitated, and there is a loss of hardness. Each degree of loss equals ·24 mgm. of sulphur tetroxide (SO_4).

1632.—*What is the significance of sulphates in water?*

If unassociated with any special geological features which would account for the presence of an unusually large amount of sulphates, their existence in excessive quantity, taken in conjunction with chlorides, organic matter, ammonia, etc., is corroborative evidence of sewage contamination.

1633.—*What is the best test for phosphates ?*

The molybdate of ammonia test. We take a little dilute HNO_3 and a little solution of molybdate of ammonia, the solution is heated and it gives a *marked yellow colour,* the formation of "phosphmolybdic acid," which is yellow. The difficulty is to get the reagents quite pure for they give reaction to phosphates; therefore test the reagents first and compare the solution test in depth of colour. The water to be tested may require to be boiled down to $\frac{1}{10}$ or even $\frac{1}{50}$ of its volume, 250 C.C. being boiled down to 5 C.C. before the presence of phosphates can be elicited with the reagent.

The test solution for the molybdic test may also be made by taking some pure molybdic acid and dissolving it in solution of ammonia (·960 sp. gr.). Filter, and then pour the solution into nitric acid (1·20 sp. gr.). Keep the solution in the dark, and decant, if necessary, from any precipitate.

1634.—*What is the indication from the presence of phosphates ?*

Phosphates may be present in water where there is sewage pollution, but they seldom exist, except in the smallest traces, as phosphates, being acid salts, are incompatible with calcium carbonate. Where sewage pollution is suspected they should be always tested, for phosphites usually point to remote animal pollution, and so their mere presnce without other reasons does not justify the condenmation of the water.

1635.—*What is the test for lime in water ?*

The addition of a solution of oxalate of ammonia to water containing lime gives a white precipitate ; 6 grains of lime to the gallon gives a turbidity only ; with 16 grains there is a considerable precipitate.

1636.—*What is the test for iron in water ?*

Red and yellow prussiates of potash give a blue precipitate. The red prussiate is used for ferrous, and the yellow for ferric salts.

1637.—*Briefly state how we may test for lead, iron or copper in water?*

Acidify the water with hydrochloric acid and add sulphuretted hydrogen solution. Any brown colour developed, shows the presence of lead or copper. Add ammonia sulphide solution. This produces a dark colour, not cleared up by hydrochloric acid. Place some water (100 C.C.) in a white dish, and stir up with a rod dipped in ammonia sulphide, wait till the blue colour is produced, then add a drop or two of hydrocholoric acid. If the colour disappears, it is due to iron ; if not, to lead or copper.

Sulphuretted hydrogen gives a white precipitate if zinc is present. This test is not available if there be iron present, or should the water be alkaline. It only holds good for prefectly neutral waters containing zinc.

1638.—*How is the presence of ammonia determined in water ?*

For the determination of ammonia, we add a few drops of *Nessler's solution* to the water. A yellow colour or yellowish-brown precipitate occurs, in accordane with the amount of ammonia present. By experience we learn the amount of ammonia present from the degree of colouration produced in this reaction, although for exact analysis the quantitative method must be employed. If the ammonia is small in quantity, several inches in depth of water should be looked through on a white ground.

1639.—*Give a rough test for the presence of organic matter.*

A few drops of permanganate of potash (Condy's fluid) mixed with water containing organic matter, imparts to it a dull, cloudy appearance, after an interval varying from a few minutes to a few hours, according to the foulness of the water.

1640.—*What are the ordinary tests for the presence of oxidisable matter including organic matter in water?*

About 250 cubic centimetres of the water is evaporated to dryness in a porcelain or platinum vessel. By further heat, the residue assumes a brown or black colour if much organic matter is present, and if nitrogen is present in the water, the smell of ammonia is detected. A solution of potassio-gold chloride produces a colour passing from rose pink to violet, to olive, and ultimately a black precipitate takes place The water, which should be neutral or feebly acid, must be boiled for 20 minutes with the gold chloride. If no nitrous acid be present, the reaction may be considered due to organic matter. Add to a few ounces of the water, sufficient dilute solution of permanganate of potassium to produce the faintest tinge. In the presence of organic matter, the solution will gradually become decolorised, the rapidity with which it does so depending upon the amount and characters of the organic matter present. In the absence of nitrites, the reaction indicates organic matter, if the *action be rapid*, it is probably animal; if slow, it is probably vegetable.

The presence of micro-organisms in the water may be detected microscopically after allowing the water to stand in a long narrow jar for six hours, and using the lowest ½ inch of water for the purpose.

1641.—*What is meant by degrees of hardness?*

By *degrees* of hardness we signify that a definite quantity of water decomposes a certain number of cubic centimetres of a standardised soap solution. Thus 10 degrees of hardness means that 10 C.C. of the standard soap solution have been used; that is, each C.C. of solution = 1 degree of hardness (FRANKLAND'S scale.) Each degree of hardness causes the destruction of 2½ oz. of soap in 100 gallons of water used for washing clothes.

1642.—*How may we roughly estimate the relative degree of hardness?*

A rough means of judging the relative degree of hardness of any sample of water, consists in placing a small quantity in a test-tube, and adding to it a few drops of a standard solution of soap in alcohol, when a white turbidity will make its appearance, the intensity of the turbidity depending upon the degree of hardness.

1643.—*Give a table for the qualitative examination of water?*

HARDNESS.	CHLORINE.	ORGANIC MATTER.	SULPHATES.	FREE AMMONIA.	NITRATES.	NITRITES.	LEAD OR COPPER.
To a small quantity of the water in a large test tube add a little 'Soap test,' and shake, when the degree of turbidity produced will afford a rough indication of the degree of hardness.	Acidify a little of the water with nitric acid, and add a few drops of silver nitrate solution. Four grains of sodium chloride per gall. on gives a slight turbidity, ten grains a slight precipitate, and 20 grains a considerable precipitate.	Add to a few ounces of the water sufficient dilute solution of potassium manganate to produce a faint pink colour. The solution will gradually become decolorised, the rapidity depending on the amount and characters of the organic matter present.	Acidify with hydrochloric acid, and add a few drops of barium chloride solution — a white turbidity will be produced, varying in amount with the quantity of sulphates present.	Add a few drops of Nessler test, and note the degree of brown or yellowish coloration produced.	Mix a little of the water with twice its bulk of pure sulphuric acid, then add a drop of a solution of pyrogallic acid, a pink-blue colour changing to brown indicates nitrates.	Acidify water with sulphuric acid, and add a little *pure* potassium iodide, followed by a little freshly-prepared starch solution; a blue tint indicates the presence of nitrites.	Acidify some of the water with hydrochloric acid, and add a little sulphuretted hydrogen water. Any brown coloration indicates lead or copper. Or the water may be stirred with a glass rod dipped in ammonium sulphide, and colour noticed.

1644.—*Can we, as the result of chemical analysis, determine that a given sample of water is wholesome?*

We cannot, although we may state (when such is the case) that a specimen is *unwholesome.* Chemical analysis gives complete information as to the chemical impurities of water. As far as organic matter is concerned it is not quite satisfactory, for it does not distinguish dangerous from comparatively harmless bodies. Nevertheless, if water is polluted by lethal impurities it contains associated impurities which show it chemically as dangerous. Therefore we reckon that chemical analysis is not infallible, but it is undoubtedly the best means we at present possess of estimating the wholesomeness or otherwise of a water. The qualities of organic matter cannot be definitely settled by a chemical analysis alone. Local and chemical examinations of water must, therefore, always go together; either alone may often be enough to condemn a water, but both are always required to prove sufficient grounds for a positive opinion of purity and safety of a water.

We cannot entirely pass over the question of the importance, from a sanitary point of view, attaching to a few of the chief impurities, though we must insist on the fact that the chemical composition alone is no real evidence of its wholesomeness, since analysis can only show the quantity and not the nature or condition of the organic matter. For instance, an amount of some specific pollution, as of enteric or cholera evacuation, or some particular fungoid organisms, may be too small for recognition by the chemist, or, at any rate, may not appreciably increase the total organic impurity, and yet be not merely injurious but actually poisonous. The total solids convey no further information than the fact of the hardness of a water, which may be of a perfectly innocent character as in the chalk waters, or such as to unfit it for drinking, as in the case of many liassic and gypsum waters.

When the analysis is for the purpose of stating whether a special kind of water is fit for the general supply of a town, then a great many considerations come into operation. The exact mineral character of each supply should be registered.

If a water be dirty, a knowledge of its history and, of course, of its mineral constituents may be of assistance in forming a judgment as to the degree of risk attendant in its employment for domestic use.

1645.—*Can we rely upon the results of a chemical examination of water as to its usability?*

Not absolutely, for it may fail to detect small quantities of the specific germs of disease such as micro-organisms. It is quite possible that a water may contain the *materies morbi* of enteric fever, cholera, or malarial diseases, and yet not be detected by chemical analysis; or even pass as a first class water under the same circumstances.

1646.—*What are the chief uses of chemical analysis of water?*

1. A simple analysis shows us the nature and quantity and impurities of water of a given specimen of water;

2. Repeated analyses are required to indicate change in water from the same source or different sources, or other conditions; and

3. They show the best form of testing the condition and efficacy of filters.

1647.—*What varieties of impurities may be found in water?*

Mineral, vegetable, and animal.

1648.—*Which of these is the most dangerous?*

The animal impurities have till recently been considered the most dangerous, but if we accept the germ theory of disease, we are forced to recognise pathogenic fungi as the most dangerous impurities, and these are of a vegetable nature

1649.—*What is Prof.* FRANKLAND'S *standard of maximum impurity allowable in a drinking water?*

(*a*) *Suspended matter.* More than 1 part dry organic matter or more than 3 parts dry mineral matter in 100,000. Perfect rest in subsidence ponds for at least six hours is also required.

(*b*) *Dissolved matter.* More than 2 parts of organic carbon or 0·3 of organic nitrogen in 100,000.

(*c*) *Colour.* Any distinct colour in depth of 1 inch when examined by daylight in a white vessel.

(*d*) *Metals.* More than 2 parts of any metal (except calcium, magnesium, potassium or sodium) dissolved in 100,000 parts.

(*e*) *Arsenic.* More than 0·05 of arsenic in any form per 100,000.

(*f*) *Chlorine.* More that 1 part of free chlorine (after addition of sulphuric acid) per 100,000.

(*g*) *Sulphides.* More than 1 part of sulphur as sulphides per 100,000.

(*h*) *Acidity.* More than that caused by 2 parts of hydrochloric acid per 100,000.

(*i*) *Alkalinity.* More than that caused by 1 part of caustic soda per 100,000.

(*j*) *Oily matter.* More than 0·05 parts of petroleum or hydrocarbon oil suspended in 100,000 parts, or any film of oil upon the surface.

1650.—*Give a tabular view of inferences to be drawn from a qualitative examination.*

Chlorine.	Oxidisable matter by gold chloride or silver chloride.	Nitrates.	Nitrites.	Ammonia.	Phosphates.	Sulphates.	Classification of water.	REMARKS.
Slight.	Slight.	*Nil.*	*Nil.*	*Nil.*	*Nil.*	Trace.	Good.	A perfectly pure water.
Marked	*Nil* or trace.	*Nil.*	*Nil.*	Marked	Present	Trace.	Good.	A good water, probably from a deep well.
Marked	Slight.	Marked	*Nil* or trace.	Trace.	Trace.	Trace.	Usable	Probably old animal contamination.
Large.	Slight.	*Nil* or trace.	*Nil.*	*Nil.*	*Nil* or trace.	Marked	Usable	Probably some contamination with sea-water.
Slight.	Well marked	Marked	*Nil.*	*Nil.*	*Nil* or trace	*Nil* or trace.	Usable	Probably vegetable impurity: peat?
Marked	*Nil* or trace.	Marked	*Nil* or trace.	Marked	Marked	Marked	Suspicious.	Probably a shallow well, contaminated with urine.
Slight.	Marked	Present	Present	Marked	Trace.	Trace.	Impure.	Probably water contaminated with sewer gases.
Marked	Large.	Marked	Marked	Marked	Marked	Marked	Impure.	Water contaminated with sewage.*

1651.—*What are the principal difficulties in the way of the satisfactory chemical examination of surface waters?*

The difficulties are three in number: In the first place, the volume of water is generally so large that, even when polluting matter is known to be present, the dilution is so great as to prevent the detection of unmistaken evidence of contamination. In the second place, all surface waters contain more or less of organic substances—substances containing carbon and nitrogen—which it is impossible to refer definitely to animal or vegetable sources, or otherwise to distinguish as harmless and harmful. In the third place, the water of such streams and ponds is subject to very considerable variation, so that the examination of a single sample is of comparatively little value. It may be possible, it is true, to state from the chemical examination of a single sample that no considerable or no appreciable contamination exists; it is impossible to recommend a water for drinking without knowing somthing of the situation and surroundings of the source from which it is taken.

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* PARKES' *Practical Hygiene*, 7th Ed.

1652.—*What bodies should be absent from a good drinking wàter ?*

Nitrites, nitrates, ammonia and its salts, metallic salts, excess of organic matter, alkalies, sulphides, and H_2S (sulphuretted hydrogen).

1653.—*Is it desirable that the water drunk should be chemically pure ?*

No ; a certain amount of mineral salts and free aëration are requisite in order that water may be palatable.

1654.—*What is the general state of qualitative solutions ?*

Qualitative solutions, and, generally, solutions that are not titrated or graduated, are *saturated*, unless otherwise specified.

1655.—*If a sample of alleged contaminated water were brought to you, what ready means would you adopt in order to ascertain the presence of inorganic impurities ?*

Inorganic impurities are minerals, such as lead, copper, zinc, etc., and the simplest method would be to pour out a portion into a white porcelain saucer, and treat it by chemical precipitation. The presence of lead, copper, or iron, is ascertained by adding a drop of ammonium sulphide, a dark discoloration showing that one or more of these are present. If it is iron, the addition of a few drops of HCl will cause the dark colour to disappear, if lead or copper, the colour remains and the water is unfit for use. For *zinc*, sulphuretted hydrogen gives white precipitate if iron is not present. For *lime*, oxalate of ammonia gives a white precipitate. For chloride of sodium, nitrate of silver and dilute nitric acid give a white precipitate becoming of a lead colour. For the various other inorganic impurities of water, other tests both quantitative and qualitative are available. Some of the tests involve a knowledge of chemistry and supply of chemical material to be found only in the laboratories of those conducting [illegible] analytical processes systematically.

1656.—*Give the steps for rapidly carrying out a [illegible]ysis of water.*

This is best done by shaking up some of the water in a flask with a short and wide neck, about one-third full, and then inhaling the air in the upper part of the flask. Should it smell disagreeable in any high degree, the water may be said to be unfit to drink. Now warm the water slightly and smell again ; warming will often bring out the smell of a water when none could be detected in the cold. Now add a little caustic potash to the warm water; should this cause any unpleasant smell, we may be pretty sure that the water contains organic matter in some quantity. Notice if a precipitate occurs on the addition of the potash, if so, whether much or little, whether coloured or white. The occurrence of a precipitate indicates hardness, the colour may either be caused by organic colouring matter in the water or by iron.

Add Nessler's test to about 100 C.C. of this water, either in a cylinder or small flask. Should this produce a yellow or brown colour or a brown precipitate, the water contains ammoniacal salts or rather organic matter. This is a most suspicious circumstance, and is almost enough in itself to condemn the water for drinking purposes.

Add iodide of potassium, acetic acid, and starch paste to 100 C.C. of the water. A blue colour indicates nitrites, which also is a most suspicious circumstance, and should the colour be at all deep, the water can hardly be fit to drink. It is to be noted that inasmuch as iodide of potassium often contains iodate, the acetic acid, starch and iodide should be mixed before adding them to the water, so as to make sure that the colour is really produced by the water, and not by any iodate that the reagent may contain.

Boil about 100 C.C. of this water in a flask, with a few drops of sulphuric acid, remove from the source of heat and add sulphuretted hydrogen water. Should a brown or black coloration be produced, the presence of lead or copper may be inferred, and the water condemned (bismuth, mercury and silver would, of course, give the same reaction, but are hardly likely to be present). Should no colour be detected, add a little ammonia or potash. Should this produce a blackish precipitate, iron is almost sure to be present.

Boil a little of the water for a few moments with red litmus. Should the litmus not turn blue repeat the operation with blue litmus. We learn from this whether the water has an alkaline or an acid reaction. This observation is seldom of importance, except when the water comes from manufacturing districts, it is then often of the greatest value.

The preliminary examination described above takes up a very short time, and gives us much information. It does not require more than 50 C.C. of water, and may be conducted with less.

The water used in the examination for clearness, colour, etc., is not reckoned, because it can be employed afterwards in other parts of the analysis.

We may here remark, that if a water contains suspended matter, it should in our opinion, be analysed with that suspended matter in it, but the water should be examined both before and after filtration. The difference between the two results is the value for suspended matter. This double examination extends only to the total solid residue and the organic matter. The nitric acid and chlorine will not be affected by the suspended matter. A slight difference will sometimes be found between the hardness before and after filtration, but it is not of sufficient moment to render a second determination requisite.

1657.—*What is the nature of dissolved impurities ?*

They may be gaseous or solid, and the solid may be organic or inorganic.

1658.—*Give a simple method for determining the presence of recent sewage contamination.*

On the addition of Condy's fluid the colour rapidly disappears in consequence of the presence of much fresh organic matter.

CHAPTER XVIII.

EXAMINATION OF WATER—*continued.*

QUANTITATIVE ANALYSIS OF WATER-INTRODUCTION.

1659.—*What is the object aimed at in an examination of water for hygienic purposes ?*

The analysis of water for hygienic purposes has for its object to ascertain whether the water contains any substances either suspended or dissolved which are likely to be hurtful. There are some substances which we know are not likely to do any harm, such as carbonate of sodium, calcium, and magnesium in small quantities. Others are at once viewed with suspicion as indicating an animal origin, and, therefore, being probably derived from habitations or resorts of men or animals, or from decaying bodies. In other cases substances in themselves harmless, such as nitrates, nitrites, and ammonia, are suspicious from implying the co-existence of, or the previous contamination of the water by nitrogenous substances. The difficulties in the hygienic examination of water are not inconsiderable. A judgment must be generally come to from a collation of all the evidence, rather than from the results of one or two tests.

1660.—*Can we rely upon the results of a chemical and physical examination of water as to its usability ?*

Not absolutely, for it may fail to detect small quantities of the specific poison of disease, such as micro-organisms. It is quite possible for a water to contain the *materes morbi* of enteric fever, cholera, or malarial diseases, and yet fail to be detected by chemical analysis.

1661.—*What are the more important processes conducted in a quantitative examination of water ?*

The quantitative processes which appear, in a hygienic sense, to be most useful are as follows :—

Determination of—

1. *Dissolved solids.* (*a*) Total. (*b*) Fixed. (*c*) Volatile.
2. *Chlorine.*

3. *Hardness.* (*a*) Total. (*b*) Fixed. (*c*) Temporary or removable.
4. *Free or saline ammonia* and *nitrogenous organic matter, as represented by*—
   (*a*) *Free* ammonia.
   (*b*) *Albuminoid* ammonia.
5. *Oxidisable matter* and *products of organic oxidation.*
   (*a*) In terms of *oxygen* required for *total oxidisable matter.*
   (*b*) In terms of *oxygen* required for *organic matter* only.
   (*c*) *Nitrous acid.*
   (*d*) *Nitric acid.*
6. *Phosphoric acid* in phosphates.
7. *Sulphuric acid, silica, iron,* and the *alkaline carbonates* may be determined, but are seldom required.

1662.—*What points are estimated and inquired into during an ordinary quantitative examination of water?*

Total solid matter, hardness, (temporary and permanent), chlorine, ready-formed ammonia, nitrogen existing in organic matter or "albuminoid ammonia," and nitrogen in the form of nitrates and nitrites.

1663.—*According to the R. P. C. what particulars as to water should be inquired into in conducting a quantitative analysis?*

1. Organic carbon.
2. ,, nitrogen.
3. Ammonia.
4. Nitrogen in combination with oxygen, as in nitric and nitrous acids.
5. Total combined nitrogen.
6. Colour.
7. Hardness (ascertaining the nature of the hardening constituents).

1664.—*How may we estimate purity of water?*

The only safe way of arriving at a conclusion with regard to the quality of a water is to consider the analyst's report *together with the possible sources of pollution,* and, for this reason, it is most desirable to send a full account of the surrounding conditions with the sample.

1665.—*What are the difficulties connected with an exact and complete chemical analysis of water?*

The *exhaustive* chemical examination of a sample of water is one of the most tedious and troublesome operations known to chemists. It requires weeks, sometimes even months, for its completion. This arises partly from the great multiplicity of separate substances which may be present in the water, both in solution and in suspension, partly from the very minute proportion in which these substances sometimes exist, and partly on account of the difficulties attending their exact determination.

1666.—*What amount of water is required for analysis?*

One Winchester quart. [Seventy C.C. is used for each distinct operation, with one or two exceptions. A gallon contains 70,000 grains. Seventy C.C. is styled a "miniature gallon."]

1667.—*In general terms what may be said to be the effects of impure water on public health?*

Although impure water has long been recognised as one of the most potent causes of disease, it is only of recent years that minute investigation has succeeded in demonstrating the terrible mortality which it inflicts on all classes of the community. It is true that chemical analysis often fails in detecting the special impurities on which the development of certain diseases depends; it is also true that, even when impurities are detected, it is extremely difficult to estimate their exact etiological value; nevertheless, the broad fact remains, and it is founded on evidence of the most conclusive kind, that a large number of cases of disease are attributable to the use of impure water, and there are good grounds for believing that, as investigations become more frequent and precise, a continually increasing class of such cases will be discovered. It must also be remembered that the effects of impure water, like the effects of impure air, may engender a general impairment of the health, without giving rise to well-pronounced disease.

When carrying out a qualitative and quantitative examination, we may conduct these under the several headings of chlorine, nitrates, nitrites, etc., (qualitative), and solids, ammonia, etc., (quantitative).

A determination of the nature of these is not frequently necessary, and a quantitative determination of each of them is seldom of much service for the purposes of sanitation. If required, special precautions are necessary, and some of the operations must be conducted at the spring or well, as the case may be. The presence of any special odorous gas, such as sulphuretted hydrogen, may be noted.

The very numerous animal and vegetable substances derived from habitations are usually classed under the vague, but convenient term of "organic matter," as the separation of the individual substances is impossible. The organic matter is usually nitrogenous, and FRANKLAND has proposed to express its amount in terms of its nitrogen (organic nitrogen), but this view is not now generally received on account of the difficulty of estimating the very small quantities sometimes found.

When a water is much discolored from impurities, there is no difficulty in obtaining enough of the sedimentary matter for microscopical examination. But sometimes the sediment is so small in amount that several slides may have to be examined before anything is met with. When this is the case, a long narrow cylindrical glass, thoroughly cleaned, should be filled with the water to be examined, allowed to stand for 24 hours, and then the water to within ¼″ from the bottom should be siphoned off, and preparations made from it in the ordinary way.

1668.—*Is it always an easy matter to be able to express a definite opinion as to the quality of water?*

There is no difficulty in condemning a water which is very bad or in pronouncing a water very good; the difficulty begins when the pollution is small in amount and doubtful in character.

1669.—*What factors are employed in the conversion of parts per* 100,000 *into grains per gallon, or the reverse?*

1. To convert parts per 100,000 into grains per gallon, multiply by 7 and move the decimal point one place to the left.

2. To convert grains per gallon into parts per 100,000, multiply by 10 and divide by 7 or shortly divide by ·7.

3 To convert grains per litre into grains per gallon, multiply by 7.

1670.—*What are the various equivalents of* 70 *C.C. of water?*

70 C.C. of water 70,000 milligrams. A gallon of water weighs 70,000 grains; 70 C.C. of water is therefore a sort of miniature gallon in which the milligram is related to the grain; for instance, knowing the residue left by 70 C.C. in milligram, we at once know the number of grains of solids per gallon.

1671.—*How may we convert into parts per* 100,000 *from grains per gallon?*

By dividing by 7; or, what comes to the same thing, by multiplying by 10 and dividing by 7.

1672.—*How are the results of quantitative examinations usually stated?*

The statement of results is usually given in English-speaking countries in grains per gallon, or in parts in 100,000; but it may be given in grammes per litre, which is the same as parts per 1000, and by shifting the decimal point to the right, parts per 10,000, 100,000, or per 1,000,000 are obtained. It is much to be desired that one uniform mode should be definitively adopted, in order to avoid the confusion which at present undoubtedly exists.*

1673.—*How may we convert parts per million* (*i.e.*, *milligrammes per litre*) *into grains per gallon?*

By multiplying by the factor ·07

1674.—*How may we convert grains per gallon into parts per million?*

By multiplying by the factor 14·3.

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* PARKES' *Practical Hygiene*, 7th Ed.

1675.—*Give the results of any analysis you may have made.*
analysis by Mr. G. Palmer, *on 6th May* 1890. *Analyses*

No. of Samples.	Localities where Samples were taken.	Total Solids, grains per gallon.	Degree of Hardness (Clarke's scale) Total.	Chlorine, parts per 100,000.
1	From the Hussain Saugor Tank near the village of Khairatabad, and near the out-fall of the Bulkapur channel, (no water running in the channel at the time).	17·5	7°	2·5
2	From the Hussain Saugor Tank close to the Nampully sluice, and over the sluice opening, through which the water for the Residency and Chadarghaut supplies flows.	18·5	6·5°	2·3
3	From the chamber in the Residency filter beds whence the water flows on to the sand of the filters. The water in this chamber has passed through a wire sieve of 400 meshes to the square inch.	14·2	7·5°	2·4
4	From a stand-post in the Residency Bazars (at Ramkote). This water has been filtered and is in the state in which it is supplied to the public.	12	5·8°	2·2
5	From near the centre of the Hussain Saugor Tank, about the deepest part.	16	6·75°	2·5
6	From the Hussain Saugor Tank under the Railway Bridge, where the pump for the Railway supply is situated. Through this bridge sewage falling into the tank from Secunderabad must flow into the main body of the Tank.	17	5·8°	3·2

1. The water of samples 1, 2, and 6 are unwholesome. They would be considerably improved by filtration, but nothing short of boiling and filtration would render them potable.

2. Samples 3 and 5 would be rendered wholesome by due filtration, but are in their present state impure and unpotable.

3. Sample 4 is a "pure" wholesome water. With the exception of that of its "Total Solids," all its constituent impurities are in such small quantities as to lead me to consider it a first class water.

4. With regard to the quantity of total solids, total hardness and chlorine, all the samples are practically alike. Much variation however is found in the amount of "Free and Albuminoid Am-

Report on six samples of water numbered 1, 2, 3, 4, 5, 6, *sent for carried out on* 7*th*, 8*th*, 9*th*, 10*th May* 1890.

Ammonia, Parts per 100,000.		Physical characters.	Microscopical characters of sediment.
Free.	Albuminoid.		
·00636	·004	Faintly opalescent becoming clear on standing. Greyish flocculent suspended matter, minute animalculæ floating about.	Vegetable debris; bacterioid and amœboid forms; infusoria, *wool-fibre*.
·00578	·0035	Clear; small amount of suspended flocculent matter. Few animalculæ.	Vegetable debris, monads, bacterioid forms, ciliatæ, oscillatoria in abundance.
·003	·002	Clear, trifling amount of suspended matter.	A few vegetable cells, cotton wool-fibre, infusoria.
·0015	·0012	Clear, devoid of sediment and of suspended matter.	A few vegetable spores.
·003	·0034	Clear; extremely fine particles of suspended matter, abundance of very small animalculæ.	Vegetable cells, and vegetable debris, *epithelial cells* (squamous), oscillatoria.
·00424	·0031	Faintly opalescent; suspended flocculent matter in abundance, animalculæ of various kinds.	Cellular algæ, conidia, disintegrating vegetable fibre, bacterioid forms in abundance, *starch granules*, oscillatoria, ciliata.

monia" (the standard of animal organic impurity and of contamination by human excrement), and in this respect all the samples except (4) are impure and unfit for human consumption without previous preparation by filtration, and in the instances specified, without boiling and filtration.

All (except 4) contain the lower forms of animal and vegetable life, living and dead.

None of the samples are sufficiently impure to be absolutely condemned.

[The height of the Tank on 6th May (date on which samples were taken) was 27′ 8″, or 11′ 5″ above the outlet whence the water-supply is derived.]

CHAPTER XIX.

EXAMINATION OF WATER—*continued.*

CHLORINE.

1676.—*What are the different sources of chlorine in water ?*

(*a*) Geological strata containing chlorides of sodium or calcium—especially.

(*b*) Salt of sea-water.

(*c*) Liquid excreta of men and animals.

1677.—*What apparatus and test solutions are required for the quantitative test for chlorine ?*

Graduated burette and stand ; two porcelain dishes holding about eight ounces ; standard silver solution of argentic nitrate solution of yellow potassium chromate.

1678.—*What is the strength of the standard solution of nitrate of silver ?*

There are 4·788 grammes of $AgNO_3$ per litre of distilled water. Each cubic centimetre of this solution is equivalent to one millimetre of Cl and 1·65 of NaCl.

1679.—*What is the strength of the potassium mono-chromate solution ?*

50 grammes of mono-chromate of potassium to one litre of distilled water.

[The strength of the solution is so adjusted that each C.C. of the $AgNO_3$ solution represents one part of Cl per 100,000 parts.

1680.—*What precaution is to be taken ?*

To see that the chromic acid salt is pure. It sometimes contains chlorides; its degree of impurity can be estimated by a trial with pure distilled water and allowance made for.

1681.—*How is the standard solution of nitrate of silver prepared and used ?*

By dissolving 4·788 grammes of pure $AgNO_3$ in one litre of distilled water. It is of such a strength that one cubic centimetre of it is capable of precipitating exactly one milligram of chlorine.

If some of this standard solution is dropped into a water containing chlorine a white precipitate of AgCl will go on forming until all the chlorine in the water has united with the silver. There is however some difficulty of recognising the exact point at which the formation of the precipitate ceases ; this difficulty is measured by using an indicator.

1682.—*What is the quantitative test for chlorine in water.?*

Chlorine is estimated by the volumetric solution of silver nitrate. We take 100 C.C. of the water either placed in a beaker resting on a white slab, or on a porcelain dish, just coloured with a solution of potassic mono-chromate (about 1 C.C.), and then the silver nitrate solution dropped in from a burette, until a reddish tinge is produced.

1683.—*What is the principle of this test ?*

The explanation of the test is as follows :—Silver chromate is a red salt; it is not formed until all the chlorides are first used up; upon its appearance therefore it is certain that all the chlorine is combined with silver. Each C.C. of the silver solution equals a milligramme (·001 grm.) of chlorine, so that the number of C.C. used multiplied by ·001 equals the chlorine in 100 C.C. of water. [The reaction is made more delicate by observing the tint through a solution of chromate.]

1684.—*Show by an example how the test is carried out ?*

Take 100 C.C. of the water to be tested in a white porcelain dish. Add a few drops of the mono-chromate of potassium, giving the water a slightly yellow colour. Drop in the standardised solution of $AgNO_3$ from a graduated burette, till the water becomes slightly tinged, that is, till a faint red colour occurs and remains permanent. Suppose we took 7 C.C. of $AgNO_3$ solution for the 100 C.C. of water, the water contains 7 parts of chlorine in 100,000 of water or 70 per litre. If we wish to express it in parts per gallon we have the proportion

$$100{,}000 : 70{,}000 :: 7 : x.$$

$$x = \frac{70{,}000 + 7}{100{,}000} = 4 \cdot 9 \text{ parts per gallon.}$$

To state the result as NaCl* we multiply the result by 1·65 which is 11·55 NaCl per 100,000.

1685.—*State briefly the most common method of carrying out this test ?*

Take 100 C.C. of water, add a few drops of solution of monochromate of potash, making it slightly yellow. Drop in solution of $AgNO_3$ till the water becomes slightly tinged. We go on adding $AgNO_3$ solution till a faint light red colour occurs. We read off the number of C.C. of $AgNO_3$ solution used, these represent the parts of chlorine per 100,000 parts of water.

1686.—*When a solution of silver nitrate is added to a sample of drinking water a precipitate is formed : how would you prove this to be silver chloride ?*

By its solubility in a solution of ammonia.

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* This factor is got from the atomic weights of sodium (23) and chlorine (35) that is $\frac{58}{35} = 1 \cdot 65$.

1687.—*What is the principle involved in the volumetric test for chlorine?*

The fact that silver chromate cannot exist in the presence of a solution of a chloride. The solution of mono-chromate of potassium is added primarily as an indicator, when *all* the chlorine has combined with the silver to form AgCl the red chromate of silver begins to form and deposit. The moment this change in reaction occurs the addition of the $AgNO_3$ solution ceases. [The only difficulty in the test is to definitely fix the time the change referred to takes place.]

1688.—*Why do we use the bichromate of potassium in this case?*

Because it serves the function of an indicator when all the chlorine has united with the $AgNO_3$. The silver salt itself has a greater affinity for chlorine than for the chromic acid radical, but when all the chlorine has combined with the silver salt, the latter immediately unites with the bichromate, giving a very distinct permanent reddish brown colour—that of chromate of silver. As long as any chlorides are present in the water, white silver chloride is formed, but the moment the amount of soluble chlorides is exhausted, the liquid acquires a reddish tint from the formation of red silver chromate.

1689.—*What precautions are necessary?*

That the mono-chromate of potassium is free from chlorides. With the $AgNO_3$ the water should be of an acid reaction, for chromate of silver is dissolved by acids.

If the water be acid it may be neutralised or made a little alkaline by a little solution of $Na_2 CO_3$.

[If an important analysis is being carried out a blank trial with distilled water, and with water containing a known quantity of chlorine, maybe made before beginning the analysis. If great accuracy be wanted 2 or 3 times, the ordinary volume of the water may be evaporated.]

1690.—*How do we know when the silver has combined with all the chlorine?*

The exact moment at which the formation of AgCl ceases will be shown by the appearance of the deep red chromate of silver.

1691.—*Sate briefly how the test is carried out?*

To a given quantity of water (to which has been added a small quantity of yellow chromate of potassium) silver nitrate solution (4·79 grammes to a litre of water) is dropped and stirred up after each addition; the red silver chromate will disappear so long as any chlorine is present. Stop when the red tint becomes permanent; as 1 C.C. of the silver nitrate equals 1 milligram of chlorine, the chlorine in the amount of water taken can be calculated. Neither the water nor the nitrate of silver solution must be acid, else the silver chromate will be dissolved.

Some analysts prefer to use a decinormal silver solution (17 grammes of nitrate of silver per litre) and operate on a large volume, say 250 C.C., of the water. Each 1 C.C. of this solution precipitates ·00355 gramme of chlorine; hence if 250 C.C. of water be used for titration, the number of cubic centimetres of silver solution multiplied by 0·994 gives the grains of chlorine per gallon, or by 1·42 the parts of chlorine per 100,000 of water.

Dr. FRANKLAND uses a solution of half the usual strength, and takes 50 C.C. of the water for titration. Each 1 C.C. of his nitrate of silver solution=0·0005 grammes chlorine.

1692.—*Give the details as to how the test is carried out.*

Take 100 C.C. of the water to be examined; place it in a glass vessel standing on a piece of white paper; add 1 C.C. of potassium monochromate solution, which must be free from chlorine, drop in the silver nitrate from the burette, and stir after each addition. The red silver chromate which is at first formed will disappear as long as any chlorine is present. Stop directly the least red tint is permanent. Neither the solution of silver nor the water must be acid; if the latter is acid, it should be neutralised with a little precipitated carbonate of calcium. The number of C.Cs. of silver solution used gives exactly the parts of chlorine per 100,000 of water. To bring to grains per gallon, multiply by 0·7.*

1693.—*Show by an example as to how the amount of chlorine in water is ascertained and expressed.*

Water requires of nitrate of silver solution = 4·9 C.C.
Chlorine = 4·9 parts per 100,000 parts ; or, 3·43 grains per gallon.
x = per 100,000 parts ; or grains per gallon.

In 100 C.C. of water, 1 C.C. of potassium mono-chromate, and 1·5 C.C. of silver solution gives a permanent red tint, therefore the water contains 1·5 parts per 100,000 of chlorine; $1·5 \times 0·7 = 1·05$ grains per gallon.

1694.—*What is the reaction which takes place ?*

$AgNO_3 + NaCl = NaNO_3 + AgCl.$

Say we took 7 C.C. of $AgNO_3$ solution for 100 C.C. of water, therefore the chlorine is in proportion of 7 to 100,000 of water as per decimal system in grains per gallon it = parts in 70,000 ∴ as 100,000 : 70,000 : : 7 : x.

$100,000\ x = 490,000$

x = 100,000) 490,000 (4·9 parts per gallon.

1695.—*Is there any other quantitative test for chlorine ?*

Yes, that known as the Indigo process.

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* PARKES' *Practical Hygiene.*

1696.—*How is the test solution prepared for the Indigo process?*

A standard solution of indigo is prepared by dissolving commercial indigo-carmine in water containing 5 per cent. by volume of sulphuric acid, and boiling for some time so as to sterilise the solution. It is then standardised against a very dilute solution of nitrate of potassium, which may be conveniently made of such a strength that 1 C.C.=·0001 gramme N_2O_5, or a solution containing 0·187 gramme nitrate of potassium in a litre of water. In diluting the indigo solution to the proper strength, distilled water containing 5 per cent. by volume of sulphuric acid should be used. When thus prepared the solution keeps well.

1697.—*Is it usual to find free chlorine in water?*

No; it is never found in the free state, but always as a chloride, especially as NaCl [N.B.—Analytical results however are expressed as so much "chlorine"].

1698.—*Is chlorine affected by passing through the soil, or the roots of plants in the soil?*

No, it is constant. It is not affected by the soil or vegetation. It remains as evidence of past contamination after all other evidence has ceased to exist.

1699.—*When is the chlorine test very valuable?*

When (1) a large number of wells which were not before saline have to be examined suddenly, it shows amount of contamination of sewage.

1700.—*Is the amount of chlorine a good indication as to the quality of a water?*

Yes, providing we know the source of the water and the nature of the soil through which it has passed.

1701.—*How may we distinguish the source of chlorine in water?*

When in excess from sea-water, or from geological strata, there is marked absence of either organic matter or its oxidised products. When chlorine is from liquid excreta we have invariably associated with it in the water, ammonia, nitrites and nitrates, and probably also a considerable amount of oxidisable organic matters, and sometimes likewise phosphoric acid. [An abundance of chlorine with oxidisable organic matters are indicative of recent sewage contamination.]

1702.—*How do we differentiate the source of excess of chlorine?*

If from saline strata or sea water there is an absence of oxidisable or oxidised organic matter. If from human excrement, ammonia, nitrites and nitrates are present together with much oxidisable organic matter and probably also phosphates. Vegetable contamination is not indicated by chlorine.

Ordinarily where water is found to contain excess of chlorine, sewage contamination should be suspected and a further examination called for.

1703.—*What is the inference?*

That if a given sample of water be found to be devoid of chlorine, or very nearly devoid of it, there has not been sewage contamination. [This does not hold good in India, where in consequence of the manner in which the native sits the liquid and solid excrement are separated—especially is this so if privy pans are used].

1704.—*Why is the estimation of chlorine important?*

Because it is in an indirect way an indication of sewage contamination.

1705.—*Is chlorine alone a good test for purity of water?*

No, it is not as a rule; but having ascertained the source of water and the nature of the soil it comes from, the quantity of chlorine is a good indication as to the degree of purity, although the amount of chlorine does not bear any constant proportion to the amount of polluting substances in the water. [N.B.—Chlorine is a constant element in human and animal refuse, and it is not affected by passage through the soil or by the action of vegetation. We should remember that chlorides remain as evidence of past contamination (if it arise from sewage) after all other evidence has ceased to exist.]

1706.—*What is the relation of chlorides and chlorine to water?*

Chlorine in small quantities occurs in all waters. An undue quantity, unless explained by its coming from a saline spring, or from near the sea, should arouse suspicion. The chlorides in water are important as indications of the existence of human excremental contamination, and sometimes they form a guide as to the channel by means of which sewage gains access. Hence the importance of estimating the amount of chlorine in quantitative chemical analyses. Excess of chloride of calcium and magnesium may give rise to diarrhœa.

Excessive amounts of chlorine are also found in brackish waters from wells near the sea and in certain deep well waters, so that the presence of excess of chlorine must not be taken as absolute proof of sewage contamination; as a confirmatory test it is of great value.

Chlorides, estimated as sodic chloride, may reach the proportion of 100 parts per million in organically pure water from the new red sandstone, greensand, and other saliferous formations. Brackish water also contains excess of chlorine. In general, however, good waters contain not more than about 10 or 20 parts per million, and rain water and peaty waters little or none. Water from surfaces, shallow wells, etc., may contain considerable quantities of chlorine from sewage contamination.

Upon this point the late Professor **Parkes** stated:—"The purest waters contain small quantities of chlorides, generally less than 1·5 per 100,000. Rain water generally contains 0·22 to 0·5 per 100,000. An increase in ordinary drinking water may be due to sea water, salt-bearing strata, or sewage, or other impurities. In the two former cases it is comparatively innocent, but in the last it may be an indication of dangerous contamination, in which case it is usually connected with an increase in the ammonias, the oxidisable matter, and the nitrogen acids. Sewage contamination can never take place without some increase in the chlorides, unless it be through gaseous emanations. Some deep wells contain large quantities of chlorides, but the other details of the analysis will show that this is not due to any recent contamination. Generally speaking, however, an excess of chlorine is a reason for suspicion, until a satisfactory explanation of its presence is obtained."

1707.—*What is the hygienic importance of chlorides in drinking water?*

Chlorides are always present in small quantities in water. In the Thames water at Kew, there is ·847 grain per gallon of chlorine, in the new river water 1·1, in Ulls water ·7 grain per gallon. As a rule the presence of 1 grain per gallon indicates contamination with some animal refuse, unless the water is derived from new red sandstone, or brine springs, or from the neighbourhood of the sea. But this is not universally the case as the Trafalgar Square pump water contains 16½ parts of chlorine in 100,000, and yet is regarded by **Frankland** as one of the best of waters. We may state the importance of chlorine in water, thus: its absence or the presence of only a minute quantity indicates with a fair degree of certainty, the absence of animal contamination, though, on the other hand, in exceptional cases, the purest water may contain more chlorine than the same bulk of sewage.

If the chlorine exceeds 1·5 grain per gallon, its source should be inquired into; and if there be also much ammonia, and especially albuminoid ammonia, or organic carbon present, or if the water consumes much oxygen in the permanganate process, sewage contamination may be apprehended. The deep artesian well waters of the London basin contain much chlorine and ammonia, and are wholesome; but they yield little organic carbon and albuminoid ammonia, and they consume little oxygen (from permanganate). Chorides in large amounts should raise suspicion; if they are not accompanied by any excess of organic matter they are probably derived from the sea, from salt beds, or some other mineral source, and if they do not make it brackish may, as in the Kent Company's water, mean nothing; but when these sources are excluded, and there is evidence of much organic matter, *i.e.*, ammonia, nitrates, nitrites, and phosphoric acid, and, if the pollution be recent, oxidisable organic matter, the source of the chlorides is urine. When there is, on the other hand, the salt is derived from springs, or from the sea; or it is probably attended in the one case by sodium and calcium carbonates and sulphates, in the other by magnesia, and it is generally in large amounts.

CHAPTER XX.

EXAMINATION OF WATER—*continued.*

METALLIC IMPURITIES IN WATER.

1708.—*Enumerate the metals that are occasionally found in water.*

Lead, iron, copper, zinc, and arsenic.

Lead, iron, and copper are the poisonous metals more usually met with in drinking water ; less than one-tenth grain of lead or copper, and not more than two-tenths grain of iron per gallon may be permitted.

1709.—*By what simple methods may the testing for these metals be managed ?*

The testing may be managed very simply and expeditiously, and also very delicately, by taking advantage of the formation of dark-coloured sulphurets by means of sulphuretted-hydrogen, or sulphuret of ammonia. Moreover, these metals, in very dilute solutions, do not yield precipitates of sulphuret, but yield dark-coloured solutions, the depth of which is proportional to the amount of metal present. It is therefore possible to estimate these metals by the depth of the colour.

1710.—*Upon what principle may we examine for these metals quantitatively ?*

The quantities of these metals present may be found by making use of the ammonium sulphide precipitation, and comparing with standard solutions. In practice, a glass rod moistened with ammonium sulphide is dipped into some water in a porcelain dish ; if there be any colouration, it should just be visible, and should disappear on the addition of two or three drops of hydrochloric acid if it be due to iron ; if it remain, it is due to copper or lead, and should be condemned. Arsenic, barium, zinc, manganese, and chromium sometimes find their way into drinking water from chemical and other works.

As the mere presence of such metals as lead, copper, arsenic, and zinc in appreciable quantity is enough to condemn a water, therefore it will seldom be necessary to determine their amount quantitatively.

1711.—*What are the relations of metallic saltsto water ?*

Of the *metallic salts* constituting impurities in water, *lead, iron,* and *copper* are the most important. Copper is rarely met with, and when found is usually derived from copper cooking-utensils which have not been properly tinned. Neglect in this respect is sometimes serious. We have seen several cases of slight copper-poisoning arise in this way. The possibility of this would be obviated by the use of properly enamelled cooking utensils or block steel vessels. *Iron* may be derived either from the original source of the water, the water passing through a stratum containing hæmatite ore, etc., or, in the case of public water-supplies, it may be dissolved out from the pipes. The smallest quantity, even $\frac{1}{4}$ grain to the gallon, is recognised by the palate. Such water is injurious to plethoric people, giving rise to ringing in the ears, headache, etc.

The most common and important metallic impurity is *lead*. This in the case of public water works is usually derived either from the service pipe or house cistern. An extremely small quantity of lead in the water may give rise to dangerous symptoms, if the consumption of the water is long continued. Prof. PARKES stated that any quantity over $\frac{1}{20}$ grain per gallon should be considered dangerous, and some persons have been affected by even smaller quantities.

1712.—*What are the chief sources of lead in the water?*

The soluble salts of lead from leaden pipes, or from leaden cisterns.

1713.—*Briefly state how we may test for lead, iron or copper in water.*

Acidify the water with hydrochloric acid and add sulphuretted hydrogen solution. Any brown colour developed shows the presence of lead or copper. Add ammonia sulphide solution This produces a dark colour, not cleared up by hydrochloric acid. Place some water (100 C.C.) in a white dish and stir up with a rod dipped in ammonia sulphide, wait till the blue colour is produced, then add a drop or two of hydrochloric acid. If the colour disappears it is due to iron; if it does not, to lead or copper.

With zinc, sulphuretted hydrogen gives a white precipitate. This test is not available if there be iron present, or should the water be alkaline. It only holds good for perfectly neutral waters containing zinc.

1714.—*What are the qualitative tests for lead?*

(*a*) Ammonic sulphide of ammonia will give a black colour or precipitate, not removed by acid; (*b*) 1 C.C. of cochineal solution added to 20 or 30 C.C. of the sample water, in a white dish, will give a purple or blue tint if any trace of lead is present. (*c*) A new test has been brought forward by Harvey. Two grains of crystallised bichromate of potash are added, half to a litre of sample water in a conical glass, and after stirring, allowed to stand for 15 minutes. A similar sample of lead-free water is placed alongside for comparison. As little as $\frac{1}{50}$ of a grain per gallon is said to give a perceptible turbidity. If the water is not clear, it must be previously filtered. (HARVEY's Test.)

1715.—*How may we detect lead and copper in water?*

A solution of cochineal strikes in a neutral or alkaline solution a feeble red having a faint blue tinge to a deep mauve blue, according to the quantity present. H_2S gives a brown to black colour. Lead is distinguished from copper by the ferrocyanide test. A solution of potassic ferrocyanide added to a water containing a trace of copper, gives a brown colour, or if more than a trace be present, there will be a precipitate.

1716.—*How may we estimate the amount of lead present?*

By comparing the colour produced by the natural water with that produced in an equal amount of distilled water containing known amount of lead per gallon, when both are treated with H_2S.

1717.—*Give a more accurate qualitative test for lead.*

Evaporate one or two pints of the water to a small bulk, acidify with nitric acid, and pass hydrogen sulphide. Filter, dry and ignite precipitate in a *porcelain* crucible. When cold add a drop or two of nitric acid and a little water, and test with potassium iodide (yellow precipitate) or potassium bichromate (yellow precipitate or colouration).

1718.—*Describe a process for conducting a quantitative estimation of lead in water.*

1. Put 4 oz. of the suspected water in one of the dishes, and 4 oz. of distilled water in the other.

2. Stir each with a glass rod dipped in ammonium sulphide solution.

3. Into the basin containing the distilled water, run in the standard solution of the metal that is sought to be estimated till the water is of the same shade of colour as the suspected water.

4. Calculate the result.

Thus *e.g.*, with lead, suppose 4 decems are used, then $\cdot 00090 \times 4 = 0\cdot 0036 \times 5 = \cdot 0180$ grains per pint, or ·1440 grains ot metallic lead, per gallon.

Note.—The above process is applicable to the three metals, lead, copper and iron processes.

1719.—*What apparatus are needed?*

Burette and stand, two porcelain dishes, and glass stirring-rods; ammonium sulphide, standard solution.

1720.—*What are the theories respecting the solvent action of soft waters upon lead?*

1. That it is due to organic acids in the water (acetic, humic or ulmic).

2. Due to inorganic acids.

3. Due directly or indirectly to organisms.

4. Due to absence of silica from the water.

5. Due to excess of CO_2 in water.

1721.—*What point did* ALLEN *and* WHITELEGGE *prove with regard to the action of acid soft waters in lead?*

They found that the soft waters (*e.g.*, those of Sheffield) which act freely and injuriously on lead are, in many instances at least, acid in reaction; and that the acidity may be due to the presence of fixed organic and inorganic acids, or both. The organic acids are due to the oxidation of heat. The inorganic acid may be sulphuric, arising from the influx of a ferruginous water containing a ferrous salt. On exposure the ferrous salt oxidises and splits up into an insoluble basic ferric salt, and free sulphuric acid or an acid sulphate. Such waters, when run over a weir or along a conduit, composed of broken soft limestone or chalk, have their acidity neutralised; they take up a small quantity of carbonate of calcium, and acquire additional hardness, corresponding to the excess of chalk dissolved beyond that consumed. In other cases the acidity which gives the water its lead-dissolving powers, may be due to the presence of free sulphuric acid formed by oxidation of iron pyrites in the water. [It has been recently suggested by Mr. POWER, in a report to the Local Government Board, that the biological characteristic of a water—the presence or absence of bacterial organism—may exercise an influence over its "plumbo-solvent" properties. There is also some evidence to show that leaden pipes are much more rapidly corroded when the mains are intermittently charged, than when kept under constant high pressure.

1722.—*Have micro-organisms any influence in effecting the solution of lead in water?*

Mr. W. H. POWER, having regard to the observed influence of acidity on the solvent actions of soft moorland waters on lead, offers the suggestion that the 'inscrutable behaviour' of these waters in regard to plumbo-solvent ability may be related to the agency, direct or indirect, of low forms of organic life. This suggestion, no doubt, has as its basis the circumstance that certain bacteria have been found experimentally to produce acid changes in the culture media in which they have been grown; but the results hitherto obtained with the Sheffield plumbo-solvent waters are mostly negative (Reports of the Medical Officer of the Local Government Board for 1887 and 1888, pp. 280 and 453, respectively).

After the prolonged drought of 1887, the waters in the Sheffield reservoirs ran very low, the peaty acids—derived from the gathering grounds, were not diluted to the usual extent, and a severe outbreak of lead-poisoning occurred in the town.

1723.—*What other objections may be alleged against a soft water?*

The greater danger of lead contamination, often introduced by the adoption of a soft and slightly acid water-supply, may far outweigh, from a hygienic point of view, the disadvantages resulting from the use of a water of moderate hardness.

1724.—*How may we test the action of a particular water on a lead pipe?*

A method commonly adopted is to immerse fresh-scraped clean plates of lead, 6 × 2 inches in size, in a known volume, say 500 C.C. (or, better, 1 pint = 568 C.C.) of the water in a loosely stoppered bottle capable of holding double this quantity of liquid. After twenty-four hours the strips of lead are removed and any corrosion or deposit is noted. After filtration the water is examined for the lead in the usual manner.

A better and more satisfactory plan is to take a 36-inch length of fresh well-cleaned lead pipe, of ½ inch bore, closed by means of a cork provided with a pinch-cock below, and by a cork above. The tube is rinsed with the water and then filled with it, corked, and placed in a nearly horizontal position, the pinch-cock being at the lowest end of the tube. After a definite period, say 12, 18, or 24 hours, the water is run out of the tube, and replaced by a fresh quantity, which is again withdrawn at the end of any desired period. The successive quantities of water are measured, and the lead present determined as before. In this way the action of the water upon lead (either fresh pipe or after some use) may be determined. The volume of water held by a pipe of ½ inch bore, and 36 inches in length, is one-fifth of a pint approximately, or 116 C.C.

Another practical test of the action of water on lead is as follows:—Take a beaker containing eight ounces of the water to be examined, and place in it a piece of plumbers' cistern "six-pound lead," four inches by one inch. Each square inch of the lead sheet is thus acted upon by one ounce of water. The water may be examined daily, the colour produced on the addition of sulphuretted hydrogen compared with a standard solution of lead. WANKLYN gives the following process:—Take 70 C.C. of the water, place them in a white porcelain dish, and stir with a glass rod dipped in sulphide of ammonium. If the slight colouration form which is not absolutely destroyed on acidification with hydrochloric acid, the water should be condemned as contaminated with metallic impurity—either copper or lead. Lead-poisoning may result from so small a quantity as one-ninth of a grain per gallon.

1725.—*What is the principle of the methods employed for estimating the amount of lead or iron present in water?*

In the case of lead, that of comparing the colour produced by the natural water with that produced in an equal amount of distilled water containing a known amount of lead per gallon, when both are treated with sulphuretted hydrogen. In the case of iron it is estimated in the same way; compare the blue colour produced in the natural water with that produced in pure water containing a known amount of iron; keep the tubes in the dark for twelve hours or so.

1726.—*What is the importance of the action of excess of CO_2 on lead in water?*

It has been asserted that carbonate of lead, like the carbonates of calcium and magnesium, is more soluble in excess of carbonic acid than in water, and that a bicarbonate of lead is formed when lead is present in solution in a water containing excess of carbonic acid, and experimental proof of this action has been furnished.

Hence pure rain water and distilled water corrode lead with great rapidity. If a few grains per gallon of sulphate of calcium be introduced into such a water, an adherent and coherent thin grey film of a lead compound quickly forms on the surface of the metal, and the water subsequently takes up a quite inconsiderable amount of lead; and thus the metal is preserved from further corrosion.

The deposit is very finely divided and has very little coherence, and hence when the deposit forms on the surface of the metal—as, for instance, when there is simultaneous oxidation and precipitation of the lead on the surface of a leaden pipe—the hydro-carbonate does not protect the metal beneath from the further corroding action of the aërated water.

On exposure to air, the dissolved lead is soon thrown down in the form of the almost insoluble hydro-carbonate (basic carbonate of lead, or white lead).

1727.—*Has naturally oxygenated water any action on lead?*

Pure water, deprived of gases, has little or no action on lead; when, however, the water contains oxygen the lead is rapidly corroded and dissolved; the solvent action being hastened, if not actually started, by the presence of traces of carbonic or other acid. The lead dissolved appears to be in the form of a hydrate (hydrated oxide of lead).

1728.—*What may be stated with regard to our knowledge upon the question of the relation of lead to drinking water?*

That the whole subject of the action of waters upon lead, and its prevention, stands in need of further elucidation and research; and although we may in some particular instances be able to account for the action of water upon this metal, the same explanation entirely fails in other cases. Thus it has been found that whilst the addition of an alkaline silicate of sodium to distilled water will prevent the corrosion of lead by the water, the same addition in other cases, under other conditions, may fail as a preventive. Again, it is not only soft waters exclusively that act on lead, for many hard waters will have the same effect. Neither the silica theory, nor the acid theory, of the action of waters upon lead, accounts for the whole facts known; and of two apparently similar waters as to constituents, one will act vigorously upon lead, whilst the other may have little or no effect in dissolving the metal.

1729.—*Do all waters act equally on lead ?*

Many waters have little or no action upon lead, and especially the hard waters containing calcic carbonate or a moderate amount of carbonic acid. Calcic sulphate is less protective than the carbonate, and magnesic less than calcic salts. A crust is formed upon the interior of lead pipes, composed of carbonate and sulphate of lead, lime, and magnesia (or such of them as are present in the water), and chloride of lead. Carbonate of lead is difficult of solution except in water charged with excess of carbonic acid under pressure. Pipes which are new, which are bent against the grain, or which are alternately full and empty, are more attacked than others. The maximum amount of lead is found in water which has stood for some time in the pipes, over night for example. Lead is now chemically purer than usual in former years, owing to the profitable removal of silver andother metals with which it is found associated, and it would appear that the purer lead is more readily acted upon by water.

1730.—*In what ways do natural waters act on lead ?*

Natural waters are found to act in a variety of ways on lead, and as drinking water generally meets with lead either during its conveyance from the water reservoirs to the consumer through pipes of that metal, or by being stored in leaden cisterns, it becomes of the utmost importance that the conditions under which the natural waters become charged with lead should be known. There is one broad fact which may be taken in connection with this subject, that "hard" waters have, as a rule, very little, if any, action on lead, while soft waters invariably dissolve more or less of that metal. Hard water stored in leaden cisterns cause a coating of insoluble lead salts to form on the surface of the metal which protects the lead from the further action of the water. The salt having the most protective action is the *sulphate*, and as ordinary hard waters contain, as a rule, earthy sulphates, we are able to use such waters with impunity. On the other hand, as soft waters have no such protective properties, they become more or less charged with lead and the oxide dissolved in the water.*

1731.—*What processes have been adopted to prevent lead-poisoning in cases of water containing it ?*

Various remedial measures have been tried, but, with few exceptions, not in a sufficiently thorough way. To neutralise the acidity of the water it has been exposed to fragments of limestone, and the conduits have been lined with the same material, but the limestone soon becomes inert, probably by incrustation, and frequent renewal of the surface is necessary. Measured quantities of lime have also been added to the water, and powdered chalk has been proposed for use in like manner. Water has also been charged with traces of silica by filtration through powdered granite or flint. More evidence is needed before any final conclusion can be arrived at, and it is at least possible that the mischief may not always be due to the same cause.

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* First, lead forms an oxide which is dissolved, the oxide absorbing CO_2 is deposited as a hydrated basic carbonate.

1732.—*What waters act most on lead?*

All "soft" waters; pure water; those containing organic matter, nitrites, nitrates, and those highly oxygenated.

1733.—*What waters act least on lead?*

Hard waters, especially those containing an abundance of sulphates, carbonates and phosphates of lime and magnesium, alkaline phosphates, and carbonic acid.

1734.—*How is water protected from the action of lead in these cases?*

Because an insoluble crust of phosphate or sulphate is formed on the inner surface of the pipe, which is protective and impermeable.

1735.—*What salt has most protective action?*

The salt having the most protective action is the sulphate; and as ordinary hard waters, as a rule, contain earthy sulphates, we are able to use such waters with impunity. On the other hand, as soft waters have no such protective properties, they become more or less charged with lead. Waters containing nitrates or nitrites in solution are especially to be avoided, as such waters exercise a powerfully solvent action on lead; and these salts have been known to corrode that metal to such an extent as to eat holes in the cistern in which the water was stored.

1736.—*In general terms what bodies attack lead most?*

Any water containing air, oxygen, nitrites, nitrates, or chlorides, organic acids (either animal or vegetable). [Rain water, water containing sewage, and water rich in vegetable acids are particularly liable to act on lead and dissolve it.]

1737.—*What is the limit of lead allowable in water?*

One-twentieth of a grain per gallon. This is likewise the limit detectable by chemical examinations.

1738.—*What rule then would you lay down with regard to water containing lead?*

Condemn all waters containing it, for when it is present even in very small quantities, negligence, accident, or mismanagement may at any time increase its amount to a seriously injurious extent. [To state the matter in other words,—no water should be used for drinking which contains more than one part of lead per million, for any trace however small is dangerous.]

1739.—*What limit does* WANKLYN *give?*

WANKLYN adopts $\frac{1}{10}$ gr. per gallon as the limit, above which we should be justified in condemning a water. [The author is of opinion however that any trace however small should be sufficient justification for the condemnation of the water.]

1740.—*What quantity of lead did* Prof. PARKES *consider dangerous in water?*

"Any quantity over $\frac{1}{20}$ of a grain per gallon should be considered dangerous; some persons may even be affected with less quantities."* [The best way is to avoid the use of lead as much as possible in any connection with water for drinking purposes. The consumer, however, is not entirely his own master at this point, as the use of leaden service pipes is generally insisted upon by the water companies; but cisterns need not be lined with lead, and the use of utensils made of alloys containing lead may be avoided.]

1741.—*What relation has been shown to exist between silica and the plumbo-solvent action of water?*

Certain experiments recently carried out by the late Dr. TIDY, seem to show that a water free from silica attacks lead—a discovery of considerable importance in public water-supplies. In other words, that the varying powers of corroding lead, exhibited by soft waters of apparently identical chemical composition, are due to the presence or absence of silica in the water.

When silica is present, even in the proportion of only half a grain per gallon, the action on lead is said to be very slight. There must be no excess of alkali in the water, or this inhibitive action of silica is not displayed. By passing distilled water and other soft waters known to have a corrosive action on lead through a filter formed of layers of sand, broken flints, and pieces of limestone, enough silica is taken up to reduce the lead corrosive power to one-thirtieth.

Recent experiment, however, seems to show that the alkaline carbonate, which is taken up from the limestone, may be an even more important factor than the silica. The waters of Huddersfield and Sheffield which have a considerable effect on new lead, have been rendered nearly inactive by passing them through filters constructed as above.

Dr. TIDY asserted that waters which contain less than half a grain per gallon of dissolved silica act freely upon lead, whilst those which contain more than half a grain of silica per gallon do not—except, perhaps, under exceptional circumstances—dissolve lead to any appreciable or injurious degree; and he, together with Drs. ODLING and CROOKES, have proposed to artificially impregnate waters with silica when they contain such a deficient quantity as to render them operative. Among the many substances that have been credited with increasing the solvent action of water upon lead are—carbonic acid; free mineral acids; carbon acids, the product of the decay of vegetable matters, and especially heat; organic matters; nitrates and nitrites, and chlorides—a sufficiently extended list. Among the substances which have been stated, on the other hand, to retard corrosion and solution are carbonic acid, carbonate of calcium, sulphate of calcium, phosphates, and silica, or rather dissolved silicic acid (Odling, Crookes, and Tidy). They advise that such deficiently silicated waters should be run over broken flints or a mixture of flints and chalk, or limestone, and it has been asserted that the flints are obviously dissolved during the process.

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* PARKES' *Practical Hygiene*, 7th Ed.

1742.—*Under what conditions does chronic lead-poisoning arise, and what are its symptoms?*

This form of poisoning generally occurs among painters, manufacturers of white lead, pewterers, printers, and others. The early symptoms are those of ordinary colic, only more severe. The patient generally complains, in the first instance, of feeling unwell, and of general debility. He then suffers from pain of a twisting grinding nature, felt in the region of the navel. The bowels are obstinately confined. The appetite becomes capricious, and may be entirely lost. The mouth is parched, the breath fœtid, the countenance sallow, the skin dry, and general emaciation sets in. A nasty sweetish metallic taste in the mouth is present in most cases. Not infrequently the subjects of lead-poisoning experience a peculiar form of paralysis of the upper extremities, well known as 'dropped hand.' It appears that this condition is the result of paralysis of the extensor muscles of the wrist. The muscles undergo a form of fatty degeneration. The lead appears to act primarily on the muscles, then on the nerves, and lastly on the nerve centres. One other symptom of importance has yet to be noticed. The gums, at their margins where they join the teeth, present a *well-marked blue line, absent where a tooth has been removed.* This is not present in all cases, but it should be looked for.

1743.—*Discuss in general terms the questions connected with lead-poisoning.*

Lead-poisoning undermines the health before the subject is aware of it. The proportion of lead in solution that would be injurious varies with the susceptibility of the individual. Water with as little as $\frac{1}{100}$th part of a grain of oxide of lead per gallon is said to have produced lead paralysis: whereas it is generally considered not hurtful until it contains $\frac{1}{40}$th of a grain per gallon. Some have held that from $\frac{1}{10}$th to $\frac{3}{10}$ths of a grain per gallon may be present before water is injurious to health, if used as a beverage; but this is a fatal mistake.

It is generally believed that soft waters rapidly attack lead while hard waters do not. This is by no means universally true.

Some of the softest waters have no such property. When this effect is produced, it appears to be due chiefly to the abundance of oxygen that has been absorbed in passing as rain through the air. Rain water freshly fallen, rapidly dissolves lead; but it may lose its activity by flowing for a considerable distance in an open channel, and taking up carbonic acid to a degree which may render it innocuous. Excess of carbonic acid in water materially aids its solvent power on lead. In manufacturing districts, rain water is liable to be polluted with sulphurous acids, which act violently upon leaden cisterns. In the country upland waters are apt to be charged with humic or other acids which act powerfully on lead. Oxygen, nitrous and nitric acids, all chlorides, and quicklime, also form soluble poisons with lead. Nitrate of ammonia is said to be peculiarly active when it comes into contact with this metal: and all these matters are apt to be present in soft waters.

1744.—*In what form is white lead used? What are its characters? What form of poisoning does it produce?*

White Lead, Carbonate of Lead, Ceruse or Kremser White, is used as a pigment. It is generally in the form of white, heavy, chalky masses insoluble in water, and, when taken in large doses, poisonous. It is this substance which, in the majority of cases, causes chronic lead-poisoning, or *painter's colic.*

The *chloride* and *nitrate*, the oxides, *litharge* and *red lead*, are all poisonous; but the *sulphate*, due probably to its insolubility, appears to be inert.

1745.—*What substitutes for ordinary lead pipes are now available?*

There are many of these now accessible, and where there is any tendency to solvent action, one or other of these should be adopted. Compound pipes have long been in use, the interior of which is block tin and the exterior lead; the two metals are solidly united throughout, and the pipe can be bent without fracturing the tin. A less reliable protective lining to lead pipes may be found in tar, bitumen, or lead sulphide. Iron pipes are more satisfactory in every respect, except their rigidity, which renders them difficult to adapt to the bends and turns which are needed in houses. Plain iron pipes may be employed, with some risk of trouble from rusting. Glass-lined or galvanised iron pipes are often used, and among other protective coatings may be mentioned Angus Smith's varnish. Theoretically, the rustless Barff iron offers the greatest advantages for this purpose; iron pipes of ordinary construction are exposed while hot to superheated steam, and thereby acquire a thin coating of magnetic oxide, Fe_3O_4, which renders them free from liability to rust as long as the coating is broken.*

's *Hygiene and Public Health.*

1746.—*What are the chief symptoms of lead-poisoning?*

Among the symptoms caused by lead-poisoning are dyspepsia, constipation, colic, paralysis of the extensor muscles of the hand leading to wrist-drop. A characteristic blue line appears along the edges of the gums, due to the formation of sulphide of lead in the tissue. It has been observed that abortion is common in districts where lead-poisoning prevails, and sometimes to such a degree as to materially lower the birth-rate.

1747.—*What are symptoms of chronic lead-poisoning?*

(*a.*) This form of poisoning generally occurs among painters, manufacturers of white lead, pewterers, and others. The early symptoms are those of ordinary colic, only more severe. The patient generally complains, in the first instance, of feeling unwell, and of general debility. He then suffers from pain of a twisting, grinding nature, felt in the region of the navel. The bowels are obstinately confined. The appetite becomes capricious, and may be entirely lost. The mouth is parched, the breath fœtid, the countenance sallow, the skin dry, and general emaciation sets in. A nasty sweetish metallic taste in the mouth is present in most cases. Not unfrequently the subjects of lead poisoning experience a peculiar form of paralysis of the upper extremities, well known as "dropped-hand." It appears that this condition is the result of paralysis of the extensor muscles of the wrist. The muscles undergo a form of fatty degeneration. The lead appears to act primarily on the muscles, then on the nerves, and lastly on the nerve centres. The gums, at their margins where they join the teeth, present a *well-marked blue line absent where a tooth has been removed.* This is not present in all cases, but it should be looked for.

(*b.*) Chronic lead-poisoning, seen in type-setters, type-founders, painters, potters, and others. General symptoms: Lead line on the gums, lead anæmia, and lead cachexia. Important groups of symptoms are lead colic; violent colicky pains, radiating from the umbilicus, usually constipation, exceptionally diarrhœa, abdomen concave and hard; vomiting; hard slow pulse. Temperature usually normal. Urine sometimes contains a trace of albumen, duration one or two weeks.

With regard to the minor effects of lead-poisoning Dr. B. W. RICHARDSON remarks that "contamination of water, both hard and soft, impure and pure, by lead, is, in all parts of the kingdom and under every variety of circumstances, the cause or source of various obscure diseases of man (and also doubtless, of the lower animals), of the nature of dyspepsia and colic especially.

1748.—*What are the various ways in which lead-poisoning may be produced?*

Lead-poisoning may result from—

(*a.*) Constant contact with lead and its salts in manufactories.

(*b.*) Its use in the arts and as a pigment. The injurious effects of this substance are strikingly seen among painters, the makers of glazed cards, and the workmen engaged in preparing Brussels lace—this material being whitened by beating white lead into it. All thus employed are liable to suffer more or less from chronic lead-poisoning.

(*c.*) Its application to the surface of the body in the form of ointment, plasters, cosmetics, and hair-dyes.

(*d.*) Drinking water impregnated with lead, from being stored in leaden cisterns or conveyed in leaden pipes.

"The action of water upon lead is much modified by the presence of saline substances. It is increased by chlorides and nitrates, and diminished by carbonates, sulphates, and phosphates, and especially by carbonate of lime, which, held in solution by excess of carbonic acid, is a frequent ingredient of spring and river water. But water highly charged with carbonic acid may become dangerously impregnated with lead, in the absence of any protecting salt, in consequence of its solvent power over carbonate of lead. In general, water which is not discoloured by sulphuretted hydrogen may be considered as free from lead; but there are few waters which have passed through leaden pipes, or have been retained in leaden cisterns, in which a minute analysis will not detect a trace of the metal; and were it not for the great convenience of lead, iron pipes and slate cisterns would, from a sanitary point of view, be in all cases preferable. Another case of contamination by lead may arise from electric action, as where iron, copper, or tin is in contact with or soldered into lead."

In his investigations with regard to the Devonshire colic, which formerly prevailed to a great extent, Sir GEORGE BAKER found that eighteen bottles of cider which he examined contained 4½ grains of lead, or a quarter of a grain to each bottle. The impregnation arose from lead being employed in the construction of the cider troughs.

Lead-poisoning has happened as a result of the drinking of acid wines (especially home-made) which have taken up lead from the vessels in which they have been made.

In the case of the ex-Royal family of France, many of whom suffered when at Claremont from this species of water contamination, the amount did not exceed one grain per gallon; indeed, from cases which have since occurred, it seems probable that the habitual use of water containing from one-tenth to one-twentieth of a grain per gallon may be attended with danger.

At several important towns, notably Huddersfield, Bradford and Sheffield, great complaints have been made quite recently, respecting the numerous cases of lead-poisoning that have occurred attributable to the action of peaty water upon lead, and the Local Government Board has been urged to take action in the matter.

1749.—*What measures may be adopted to prevent the action of certain waters on lead pipes?*

1. The evil effects of the employment of leaden pipes and water cisterns may be remedied by converting the inner surface of the metal into an insoluble sulphide by boiling in it a solution of sulphur with soda.

2. Carbonic acid, when dissolved in water, is a complete protection against lead-poisoning. Two volumes of carbonic acid, dissolved in 100 volumes of water, completely protect even distilled water from such contamination,

3. To remove lead from water, Professor FARADAY recommends the practice of stirring up animal charcoal with water so contaminated; the same being then allowed to settle.

1750.—*State briefly the leading points connected with the presence of lead in water-supplies.*

Some hard waters, whose hardness is due to chlorides or nitrates, dissolve lead with more rapidity than soft water; but if the hardness be due only to the earthy carbonates, the lead becomes coated instead of being dissolved. The salts of lime, too, render the water nearly harmless in this respect.

It has been stated that waters which are able to affect iron in the most decided manner are also those which are able to affect lead.

Even when soft waters do attack lead, they usually do so only while the surface is clean and bright. So soon as the metal becomes tarnished (which it does in a few weeks), the pipes are protected, and the action greatly reduced or entirely suspended.

The action of water on leaden pipes is increased by allowing it to stand for several hours, and then drawing it off.

Leaden pipes corrode more rapidly at the bends than at other places.

Tinning leaden pipes partially prevents them from being eaten away by water: but leaden pipes, lined with block tin, are the best for this purpose.

Zinc is by some regarded as almost or quite as dangerous as lead.

The water in the boilers of kitchen ranges is sometimes poisoned by the presence in them of lumps of red lead, carelessly left by workmen when putting the iron-work together.

1751.—*What is the test for iron in water?*

Red and yellow prussiates of potash give a blue precipitate. The red prussiate is used for ferrous, and the yellow for ferric salts.

1752.—*What is the test for iron in water most commonly used?*

A mixture of ferro and ferrocyanide of potash strikes a blue colour.

1753.—*How may we estimate the amount of iron present?*

By comparing the blue colour produced in the natural water with that produced in pure water containing a known amount of iron. Keep the tubes in the dark for 12 hours or so, to prevent the blue precipitate from falling to the bottom.

1754.—*How may we distinguish by chemical tests between iron, lead, and copper?*

In a glass with the water put a little iron compound; add NH_4S_2. This gives a black precipitate. But we get a black or brown precipitate with lead or copper also. Now if we add to the coloured solutions an excess of HCl, in the lead solution no change occurs if iron is present, the sulphide of iron disappears completely.

Between lead and copper the process is a long one In *lead* water, we add chromate of potash, a chrome-yellow precipitate occurs.

By addition of KI solution we get yellow iodide of lead which is soluble on heat and recrystallises, on cooling in milky crystals.

Copper compounds are injurious when habitually ingested, and hence waters containing this metal ought to be rejected.

1755.—*What reagent is required for the colorimetric test of iron?*

Dissolve 1 gramme of pure iron wire in nitro-hydrochloric acid; precipitate the ferric oxide with ammonia; wash the precipitate; dissolve in a little hydrochloric acid, and dilute to 1 litre.

1 C.C. = 1 milligramme of iron.
This is the strong solution.

For use it is diluted 1 to 100, so that

1 C.C. = 0·010 milligramme of metallic iron.
1 C.C. = 0·027 ,, of iron phosphate.*

1756.—*Give an example as to the method of calculating the amount of iron in water.*

Suppose 500 C.C. of a water was oxidised with permanganate and made up to 1 litre. Of this 50 C.C. gave as much blue colour with ferrocyanide as 0·5 C.C. of the standard iron solution with 50 C.C. of distilled water. Then 0·5 × 0·1 × 20 = 1 milligramme is the quantity of iron in 500 C.C. of the water under examination; and 1 × ·2 = 0·2 is the iron per 100,000 parts; and 1 × 0·14 = 0·14 is the grains of iron per gallon.

In operating upon chalybeate waters greater dilution is necessary; but the results are sufficiently accurate for all ordinary purposes.

1757.—*What are the properties of chalybeate waters?*

Waters containing iron salts are nauseous, stain linen, and are unfitted for drinking and washing purposes. All natural waters, perhaps, contain some small trace of iron compounds, but not sufficient to communicate a perceptible flavour to the water.

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* PARKES' *Practical Hygiene*, 7th Ed.

It is an ingredient in many natural waters, to which it gives a characteristic inky (chalybeate) taste. It is also frequently derived from iron tanks or pipes through which the water has passed. Water is unsuitable for drinking if it contains more than one grain of iron per gallon—that is, 15 parts per million. Ferruginous waters are said to be liable to cause dyspepsia, headache, and malaise in those unaccustomed to their use. Iron adds to the hardness of water.

Chalybeate waters should, if better water is procurable, be rejected as unfitted for domestic supplies.

1758.—*What metals have been particularly investigated in their relation to water ?*

Of the metallic ingredients, the effects of iron and lead have been the most fully ascertained. It would appear that iron if present in quantities large enough to impart a chalybeate taste to the water, often produces headache, slight dyspepsia, and general malaise, while impregnation with lead from leaden cisterns or pipes has frequently been followed by symptoms of lead-poisoning.

1759.—*What amount of iron gives a chalybeate and astringent taste to water ?*

About $\frac{1}{3}$rd of a grain.

1760.—*In what way does zinc get into drinking waters ?*

Sometimes from galvanised iron vessels. A thin layer of zinc coats the iron. Water containing nitrates, etc., soon attacks the zinc and corrodes the iron.

1761.—*What is the ordinary test for zinc ?*

H_2S solution gives a white precipitate of zinc sulphide.

Neutralise the filtrate from the processs for the detection of copper, and add ammonium acetate. A white precipitate indicates zinc as zinc sulphide. The precipitate is soluble in HCl, HNO_3, H_2SO_4.

1762.—*What is the test for copper ?*

Copper, like lead, strikes a brown or black colour with ammonia sulphide not discharged by acid.

1763.—*How may copper in water be estimated quantitativëly ?*

It may be determined quantitatively by a colorimetric process similar to that for iron or lead, the standard solution containing 1 milligramme of copper in each C.C. being made by dissolving 3·90 gramne of crystallised cupric sulphate in a litre of distilled water.

1764.—*What are the other tests for copper ?*

1. We must use its separate tests if we are to test differentially Its solution with a little solution NH_3 gives a beautiful blue colour, or

2. Yellow prussiate of potash solution gives a chocolate colour. These are not important tests, for if we are certain that a definite quantity of any heavy metal is present we condemn the water.

These tests may be conducted accurately in one process as follows :—Concentrate the water to a small bulk, acidify with nitric acid and pass hydrogen sulphide, and filter. Dry and incinerate precipitate, and then add dilute sulphuric acid. A blue colour with ammonia, or a brown colour with potassium ferrocyanide, indicates copper.

1765.—*What is the ordinary qualitative test for arsenic ?*

Concentrate the water, acidify with HCl and boil with pure copper foil. If a deposit occurs remove copper foil, wash with pure water, and heat in a reduction tube. Examine the sublimate with a lens or under a microscope.

1766 —*What quantities of arsenic or copper would be enough to condemn the water ?*

The merest trace of either of these elements should cause the water to be absolutely condemned.

1767.—*Where are arsenic and copper likely to be found in waters ?*

Only in places in which chemical industries form the sources of contamination, or where the water passes through strata containing the ores of these elements.

1768.—*What are the effects of chromium salts in water ?*

Chromium salts, especially chromates, act as virulent poisons, even when taken in small quantities. These compounds are but rarely met with in waters, and exclusively in mining districts.

1769.—*How may metallic-poisoning from the water of water-supplies be caused ?*

By pollution of drinking water with refuse from trades and drainage from metalliferous mines, or from absorption by water of the metals used in the construction of distributing pipes, tanks, and cisterns. The amounts of mercury, copper, zinc, or arsenic, which must be present in the water to give rise to symptoms of poisoning have not been ascertained; as regards lead as little as $\frac{1}{10}$th grain per gallon may produce plumbism in predisposed persons. In the case of the poisoning of Louis Philipp's family at Claremount, $\frac{7}{10}$th grain of lead was found in each gallon of water.

1770.—*What is the relation of organic pollution to the metallic impregnation to water ?*

Occasionally animal organic matter acts in an indirect way by producing nitrites and nitrates which act on metals.

Dr. **Bædeker**, a physician in Welldon, was called to some cases of sickness produced apparently by water. On examining this point he found the water was drawn from a pump with a copper cylinder, and contained a considerable quantity of copper, which seemed to be in combination with some organic matter. Dead (as might have been anticipated) was also largely present in this water as leaden pumps were used; iron, on the contrary, was not dissolved.

1771.—*What is a simple test for the presence or absence or injurious metals in water?*

The water should yield no colouration, or only the faintest tint of colour, on the addition of tincture of galls (absence of excess of iron), and it should not darken on the addition of a drop of sulphide of ammonium followed by a drop or two of strong hydrochloric acid (absence of lead and copper).

1772.—*Is the presence of metals in the subterranean strata an important item of information in deciding as to whether a particular water is suitable for town supply?*

The water of mountainous districts, especially where metals abound, as in Cumberland and Derbyshire, should be very carefully searched for metals. In deciding upon the water-supply to a town, the question of the possible presence of poisonous metals assumes great importance, since it is by no means certain that filtration is capable of removing such impurities.

It is only necessary to mention the fact of metals passing into the drinking water, either by trade refuse being poured into streams, or by the water dissolving the metal as it flows through pipes or over metallic surfaces.

1773.—*When is arsenic, copper, or mercury found in drinking waters in injurious quantities?*

When streams are polluted by the washings from mines or chemical works.

Zinc, copper, and arsenic, although rarely occurring in natural waters, may occasionally gain access by means of trade pollution, or by the solvent action of water (especially water containing organic matter, nitrites, and nitrates) upon the pipes and vessels with which it comes into contact.

1774.—*Does the presence of zinc, or copper, or arsenic militate materially against the usability of a water?*

Yes. Any trace of any one of these substances renders a water unfit for drinking purposes.

1775.—*What is the influence of barium compounds in minute quantities?*

The effects of barium salts taken continuously in small quantities is but little known, and of little practical interest to the sanitarian.

1776.—*Is the presence of metals in a water-supply of importance?*

In this respect metallic contamination forms the most fatal of all objections to drinking water, and is far more difficult to remedy than organic contamination, which may be got rid of completely by proper filtration. London has, perhaps, had a most fortunate escape in the collapse of the great scheme for bringing water to it from the lake district of Cumberland.

Metallic-poisoning may be caused by pollution of drinking water with refuse from trades, and drainage from metalliferous mines, or from absorption by water of the metals used in the construction of distributing pipes, tanks, and cisterns. The amounts of mercury, copper, zinc, or arsenic, which must be present in the water to give rise to symptoms of poisoning, have not been ascertained ; as regards lead, as little as $\frac{1}{10}$th grain per gallon may produce plumbism in predisposed persons.

1777.—*What refuse is particularly noxious ?*

The refuse from the operations on lead, zinc, copper, arsenic, tin, and baryta mines. In these the water is poisoned at once.

Pure water should contain no *heavy metal,* although a trace of iron may be found sometimes. In some cases iron seems beneficial, as it helps to oxidise the organic matter. The presence of any other *heavy metal* ought to condemn the water.

CHAPTER XXI.

EXAMINATION OF WATER—*continued.*

SOLIDS IN WATER.

1778.—*What are the points to be considered in connection with the quantity of solids in water ?*

No drinking water should contain an excess of *solids,* especially when these solids consist of lime and magnesium salts. Eight grains to the gallon is the limit in a first class water, and one grain of this alone should be dissipated on heating. Should the solids consist chiefly of chalk, not more than 14 grains should be present. Some authorities, however, permit of a much larger amount of solids when they are purely of a mineral nature.

1779.—*How are the dissolved solids of water determined ?*

The solids are determined by evaporation. If very good scales are available, 200 C.C. of the water are sufficient, if the scales are inferior, 500 or 1000 C. C. of the water must be taken ; then evaporate to dryness with a moderate heat, taking care that the water does not boil, else there may be loss from spurting. If the smaller quantity be taken, the whole evaporation may be conducted in one vessel (of platinum if possible) ; but if the larger amount must be used, the evaporation should be commenced in a large evaporating dish, and the concentrated water and deposit, if any, transferred into a small weighed crucible. The transference demands great care, so that none of the solids shall remain encrusted in the evaporating dish. All the contents of the large dish being transferred, evaporate to complete dryness in an air, water, or steam bath, at 212° Fahr. (100° C.). Weigh as soon as the capsule is cold, as the dried mass may be hygroscopic.* [If possible the water should be clear by allowing any contained solids to subside and not by filtration. If the residue in the evaporating dish blackens when it is incinerated over a flame, the presence of organic impurities is indicated, and should a bad smell be given off at the same time, it may be inferred, that some of these impurities are of animal origin. Another test is that of holding a piece of filtering paper which has been steeped in a solution of potassium iodide and starch and afterwards dried over the dish during incineration, if this becomes blue, it shows that nitrous acid fumes are being given off which almost always arise from animal, and not from vegetable matter. According to Dr. PARKES the total solids in good water should not exceed 8 grains per gallon, unless it be a chalk water in which case they should not exceed 14 grains of calcium carbonate. Usable waters may, however, contain as much as 30 grains. The organic matter should scarcely blacken on incineration, or, if the blackening is considerable, it should be ascertained to be chiefly due to the presence of vegetable matter.]

1780.—*How do you estimate the total residue or "total dissolved solids"?*

By carefully evaporating a pint (20 ounces) of the water to dryness, and then heating for some time at 150° C., until the residue ceases to lose weight: this=the amount of the "total dissolved solids."

1781.—*What is to be done next?*

Heat the above to redness for a few seconds, and weigh again.

1782.—*What does this give you?*

The loss of weight is=the amount of "volatile residue."

1783.—*Of what does it consist?*

Destructible organic matters, nitrites, ammoniacal salts and sometimes chlorides.

1784.—*How are the fixed solids determined?*

Incinerate the dried solids at as low a heat as possible; watch the process, and note if there be much blackening, or if any fumes can be seen, or any smell be perceived as of burnt horn. A piece of filtering paper dipped in solution of potassium iodide and starch, and then dried, or a piece of ozone paper, should be held over the crucible to detect any nitric oxide which may be given off.*

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* PARKES' *Practical Hygiene*, 7th Ed.

1785.—*How are the results of the quantitative examination of solids expressed?*

The results may be expressed in various ways, but most usually they are stated as parts in 100,000 (which is, of course, equal to centigrammes per litre), or grains per gallon (*i.e.*, parts in 70,000).

1786.—*Give an example.*

Total solids.—200 C.C. dried:—

Weight of dish and residue	. . .	19·27 grammes.
„ of dish alone	. . . .	19·23 „
Difference	. .	0·04

being weight in gramme of total solids in 200 C.C. of water.

To bring to centigrammes per litre, or parts per 100,000:
0·04 × 500=20=centigrammes per litre, or parts per 100,000.
To bring to grains per gallon:
20 × 0·7=14·0 grains per gallon.*

1787.—*How is the amount of the volatile solids obtained?*

By subtracting the fixed solids from the total solids.

1788.—*Give an example of this?*

		Parts per 100,000.	Grains per gallon.
Total solids	=	20 0	14·0
Fixed „	=	15 0	10·5
Difference, being volatile solids,		5·0	3·5

1789.—*How are the fixed solids estimated?*

The dried total solids having been weighed are incinerated and then weighed again, this result gives the fixed solids.

[If, as sometimes happens, the "total solid residue" consists of deliquescent salts, the residue must be weighed at once after evaporation.]

1790.—*Give a complete example as to how we determine the amount of solids in water and how the amount is expressed?*

The solids are expressed as

(*a*) Total.
(*b*) Fixed.
(*c*) Volatile.

The *total solids* are got by boiling down 250 C.C. to a small quantity to be poured into a weighed clean porcelain crucible, and then evaporated over a hot air or sand bath The dried residue in the crucible is the total amount of solid matter.

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* From PARKES' *Practical Hygiene*, 7th Ed.

Suppose the 250 C.C. of water when completely evaporated weighed with the capsule

16·49 grammes, and the capsule alone weighed
16·44 „

·05, the difference=the total solids in 250 C.C. of water or ·05×4=·2 grammes per litre by moving the decimal point two places to the right(=20·0) we get centigrammes.

(*b*) *Fixed solids.*—Incinerate the solid residue of total solids contained in the capsule, and weigh the latter with its incinerated contents once more; the weight, minus that of the capsule, represents the *fixed* solids in 250 C.C. of water, which×4 gives amount per litre, and this divided by 100 gives centigrammes per litre or parts per 100,000; this latter result×·7=grains per gallon. Suppose weight of capsule plus incinerated ash= 16·46 grammes

Weight of crucible alone = 16·44 „

Difference ·02

The difference ·02 is fixed solids in 250 C.C. of water; ·02×4=·08 grammes per litre, or ·8 grammes per 100,000 parts.

We therefore use the divisor 2, because it comes to the same thing as multiplying by ,20, and ·25, and subsequently dividing by 10.

Volatile solids=total solids minus the fixed solids. In the case above mentioned.

Total solids = ·05
Fixed „ = ·02
Difference ·03×4=·12=Volatile solids.

1791.—*What is the limit of "total solids" in a first class water?*

Eight grains.

1792.—*How much of this should be volatilised by heat?*

Not more than 1·5 grains.

1793.—*Is this of much importance?*

At the present day it is not considered to be of much significance because it does not indicate the nature of the organic matter or volatile bodies dissipated. At one time it was reckoned an important part of water analysis.

1794.—*Does this limit of total solids hold good for chalk waters?*

No; but even in these not more than 14 grains should be contained in a gallon. The general opinion is here given. Some authorities hold that as much as 40 grains of calcium carbonate may be contained in water without injury to health.

1795.—*When is the result given by the loss on ignition valueless?*

The "loss on ignition" or the so-called "organic and volatile matter" is of no value whatever in the case of well water or of other waters giving a considerable amount of solid residue; this is especially the case when there is a large proportion of chlorides and nitrates.

[The loss on ignition may be stated as "volatile substances." It consists of destructible organic matters, nitrates, nitrites, ammoniacal salts, combined water, combined carbonic acid, and sometimes chlorides. The variableness of the composition of the "volatile substances" has led to the disuse of the process by ignition as too uncertain. Combined with other evidence it gives, however, some useful indications. The incinerated solids may be examined for silica and iron.]

1796.—*In heating the total solids how may we judge of the nature and amount of organic matter?*

1. By the smell—that of burnt feathers points to animal organic matters; that of burnt bread shows the presence of vegetable organic matters.

2. The extent of charring produced; organic matters invariably blacken when heated: thus 2 to 4 grains per gallon causes a blackish hue in dish; 5 to 8 grains gives a distinct blackening, and 9 to 12 grains gives a very decided black colour.

[We may detect nitrous acid from nitrites by means of ozone paper, or paper impregnated with KI, and starch solution; this is moistened and held over fumes arising from the crucible.]

WANKLYN remarks that if the solid residue does not exceed 30 or 40 grains per gallon the amount of solids affords no reasons for rejecting the water for domestic use.*

1797.—*Show by another example and figures how the amount of solids dissolved in water is ascertained?*

DISSOLVED SOLIDS—

Weight of clean crucible = 16·92 grammes
,, of crucible after evaporation = 16·99 ,,
,, ,, incineration = 16·97 ,,

(*a*) *Total Solids* = ·07 × 4 × 100 = 28 parts per 100,000; or (28 × ·7), 19·6 grains per gallon.

(*b*) *Volatile Solids* = ·02 × 4 × 100 = 8 parts per 100,000 or 5·6 grains per gallon.

(*c*) *Fixed Solids* = 20 parts per 100,000 parts or 14 grains per gallon

1798.—*Does the amount of total solids in water vary?*

Yes, they vary within very wide limits, some containing only a few grains, others such as selenitic and some sandstone waters containing as much as 250 parts per 100,000.

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* *Water Analysis*, 7th Ed., p. 22.

1799.—*Name some waters containing a very small amount of total solids?*

Pure upland surface waters contain very little, sometimes not more than 3 to 4 parts per 100,000. The Loch Katrine water, supplied to Glasgow, yields only 2·4 per 100,000; Thirlmere Lake, proposed as the supply for Manchester, about the same; and Vyrnwy, proposed as the supply for Liverpool, 3·4 per 100,000.*

The amount of solids even in a good drinking water is very variable, and depends a good deal on the geological stratum of the district Dr. E. PARKES was of opinion that a good potable water should not contain more than 35 grains per gallon of solids, or 50 per 100,000 Some of the best artesian well waters in London contain over 50 grains per gallon of solids, much of which is common salt, and the highly valued table-waters imported from the continent contain nearly 100 grains per gallon of mineral constituents or 140 per 100,000. It is, indeed, rather the quality than the quantity of mineral matter present which is to be regarded in judging of the suitability of a water for domestic use. As a rule, however, those waters which contain least mineral matter are deemed most suitable for domestic supplies, though there is high authority for thinking that a certain amount of chalk in a water is beneficial. In one respect this is an advantage, for such waters, being slightly alkaline, act but little on lead, whereas the soft waters containing little solid matter are often acid, and act freely upon leaden pipes and cisterns.

1800.—*On an average what amount of solids is contained in the best upland surface water?*

About 7 parts per 100,000 or 5 grains per gallon.

1801.—*What is the significance of the loss on ignition?*

The loss which the dry solid matter obtained by evaporation of the water under examination undergoes when ignited is now-a-days but little regarded. When coupled with the manner in which the solids behave during the burning process, this determination is, however, a valuable one. The blackening, the odour, and the character as regards colour and acidity of the fumes evolved should by no means be neglected, for in this way the experienced analyst will obtain valuable information The actual amount of loss—correction being made for the substitution of the N_2O_5 radical of nitrates by the CO_2 radical of carbonates during ignition—is also an index of quality, provided chlorides and sulphates are not very abundant. When these are present, the loss is increased by the loss of water of hydration of these salts not expelled at the temperature at which the water residue was dried in the oven. In an undoubtedly good water the loss on ignition is small—1 or 2 grains perhaps per gallon—and the residue during ignition, though it may assume a shade of brown or grey, never really blackens or evolves the odour of burnt feathers.

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* PARKES' *Practical Hygiene*, 7th Ed.

1802.—*What is the maximum amount of solids that should be dissipated by heat?*

Not more than 1·5 parts per 100,000 should be volatile or dissipated by red heat. Further, the solids should blacken but slightly on heating.

1803.—*Is there any exception to this rule?*

Yes; in the case of peat water more latitude as to dissipated solids may be allowed.

After we have got solid residue the addition of a few drops of HCl causes effervescence.

1804.—*What does this show?*

This shows that they consist of carbonates.

1805.—*What is the limit of mineral salts allowable in water?*

In water for drinking it should not exceed 400 parts per million, and a good water will not contain more than 100 parts. [An excess of mineral salts in general leads to digestive disturbances, in the form of dyspepsia, diarrhœa, or constipation; but this effect is largely dependent upon the nature of the salts present.]

1806—*How may we estimate the amount of carbonates in water?*

By determining the alkalinites and measuring the degree of hardness.

1807.—*What are the varieties or classes of solid particles met with in suspended water?*

Particles of mineral matter, such as sand, chalk, mica, clay, peroxide of iron, dead animal and vegetable particles, or minute living animal and vegetable bodies.

1808.—*How may we carry out the chemical examination of the sediment?*

The amount of sediment is told by taking two equal quantities of water (say ½ litre), evaporating one quantity to dryness at once, and the other after subsidence or filtration, so that suspended matters are as far as possible separated, and then weighing the two residues. The difference between the two weights gives the amount of the sediment. Or a certain amount of water may be allowed to stand until all the sediment has fallen; the water is poured off, and the sediment dried and weighed. If good Swedish filtering paper is obtainable, the sediment may be obtained at once; two filters should be moistened with dilute hydrochloric acid, then washed with distilled water and then dried. The amount of ash in one filter should then be determined by incineration; the sediment should be collected on the other filter, dried, weighed, and then incinerated. The ash of the filter itself being known, the weight of the ignited sediment is the total weight, less the ash of the filter. If it be wished to carry the analysis farther, the sediment is incinerated, mineral matter remains, while all animal and vegetable matter, whether previously inanimate or living, is destroyed. This matter of such various origin is generally stated under the vague terms of *organic* or *volatile* matter, but this gives no idea of its origin. Some of this so-called organic matter may have been dead, another portion living. The mineral may be further determined by digesting in weak hydrochloric acid by the aid of heat; the undissolved matters are silica and aluminum silicate; lime, iron, and magnesia will be dissolved, and can be tested for.*

1809.—*What are the characters of the various mineral particles that may be met with in water?*

Mineral particles may be easily known; sand appears as large angular particles, often showing distinct conchoidal fracture; clay and marl as round smooth globules unaffected by acids; carbonate of calcium (chalk) sometimes smooth, but often crystalline, soluble in acids with effervescence. Iron peroxide appears in reddish-brown masses of an amorphous character, it is easily dissolved in hydrochloric acid, and strikes a deep blue with the ferrocyanide of potassium (yellow prussiate).*

1810.—*How are the nature and amount of mineral matter in solution determined?*

The nature and amount of the mineral matters, in solution, are determined by the soluble constituents of the various strata through which the water has passed, and the organic impurities are regulated by the facilities for pollution, in the superficial soil and the completeness of purification by filtration lower down. Hence the water in shallow wells, especially if situated near dwellings or manured lands, is liable to contain much organic matter washed from the soil, with or without partial oxidation into nitrates or nitrites; and also chlorides, which usually accompany organic impurites of sewage origin. In peaty districts the water acquires a brown tint due to vegetable matter. Boil the water, and pour it into the long clear glass. Sand, chalk, and heavy particles of the kind will be deposited, finely-suspended sewage and vegetable matter is little affected, unless it be a chalk-water, when the deposit of calcium carbonate may carry down the suspended matter. When the water is commencing to boil, smell it to see if there is any trace of sewage. Notice, also, if the ash be red (from iron). If clay has been added, it will be left undissolved by acids and water. If magnesium carbonate has been added, the ash is light and porous and bulky (Hassall).

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* PARKES' *Practical Hygiene*, 7th Ed.

1811.—*What is the nature of the vegetable solid matters which may be met with in water?*

Portions of wood, leaves, bits of the veins, parenchyma, or ducts are easily recognised. When vegetable tissue is more decomposed nothing is seen but a dark, opaque, structureless mass. Any dark formless mass of this kind in water is almost certainly decayed vegetable matter. Bits of textile fabrics (cotton, linen) are not uncommon, and are important as indicating that the water is contaminated with house refuse. So also the cells of the potato, or spiral threads of cabbage and other vegetables used by man, are of value as indications of the same kind. Spiral cells are very indestructible, and are often found in river water to which sewage gains access. Carbonaceous masses also occur, either portions of soot from coal smoke, or bits of charred wood.

Dead vegetable matter, such as woody film and portion of leaves and decaying vegetable matter consisting of confervoid growth may all be found in water which cannot be pronounced unwholesome. So also may diatomacæ, infusoria, and entomostracan.

Water collected from a peaty soil will contain large quantities of vegetable matter, while that from a soil well cultivated will be tainted with animal impurities.

1812.—*Are suspended matters injurious?*

As a rule they are practically harmless; but their presence is important as giving evidence as to the source whence pollution arises. For the most part suspended matters can scarcely be deemed injurious, but some of them, cotton fibres for example, may supply important evidence of pollution by household waste, or even sewage.

1813.—*What is the nature of the animal particles met with in water?*

Animals, or portions, such as scales from the wings of moths and butterflies; portions of the wings of insects; legs of spiders, bits of spiders' webs, and similar objects, are not uncommon; but sometimes even living animals of some size, apparently rhizopods and amœbiform bodies are met with.

1814.—*How may we determine the nature of the suspended, matters in water?*

Pour some of the water into a long glass as already described, and observe its appearance. Suspended sand or clay gives a yellow or yellow-white turbidity, vegetable humus and peat give a darkish, sewage gives a light brown colour; but the colour or turbidity alone is a very insufficient test Then boil the water, and pour it back into the long glass. Sand, chalk, and heavy particles of the kind will be deposited; finely suspended sewage and vegetable matter is little affected, unless it be a chalk water, when the deposit of calcium carbonate may carry down the suspended matter. When the water is commencing to boil, smell it to see if there is any trace of sewage.*

1815.—*Which of the various sources of water is chemically the purest as regards total solids ?*

Of the various kinds of water used for dietetic and domestic purposes, *rain water*, when collected at a distance from towns upon specially cleansed surfaces, and kept in clean receptacles, contains the smallest proportion of total solid impurity; but the organic contamination, even of such specially collected water, somewhat exceeds that of water from springs and deep wells.

1816.—*Give a rough method for estimating the amount of suspended matter in water ?*

Pass a known quantity of water through a filter paper previously washed in distilled water. The increase in the weight of the filter paper gives the quantity of total suspended matter in the known volume of the water. Burn the paper, and weigh the ash; then burn an unused filter paper previously ascertained to be precisely similar to that used, and also weigh its ash; the quantity of ash in excess of that contained in the unused filter gives the amount of suspended inorganic matter in the water.

CHAPTER XXII.

EXAMINATION OF WATER—*continued*.

AMMONIA AND ALBUMINOID AMMONIA.

1817.—*In what forms does nitrogenous matter appear in water ?*

1. As free nitrogen.
2. In combination with oxygen as nitrites and nitrates.
3. In combination with hydrogen as ammonia (NH_3).
4. In combination with CO and H in other organic forms of which albumen is taken as the type, and hence called albuminoid ammonia.

Nitrogen under one or other of the above forms is found in small quantities in all waters. Some of the chalk waters invariably contain nitrates and nitrites, probably due to fossil organic remains. The sources whence the nitrogen in water is derived vary. Rain water, especially when collected near towns, invariably contains small quantities of nitrogen in the form of ammonia, dissolved during the passage of the rain through the air.

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* PARKES' *Practical Hygiene*, 7th Ed.

The sources of nitrogenous organic impurities are chiefly of animal origin, due to infiltration from cesspools and churchyards.

1818.—*What are the sources of nitrogenous substances or compounds in water?*

1. Decay or decomposition of animal and vegetable remains in the water.
2. Infiltration of sewage.
3. Sewers discharged into the water.
4. Animal and vegetable matter brought down by drains, ditches and streamlets, or dissolved out of the earth by rain water in its passage to the tank or river.
5. By washing of clothes and bodies, and the refuse of manufactories on the river bank.
6. By animal excreta, and independent sewers.

1819.—*What are included under the term "organic matter" in water?*

1. Nitrogenous and organic matter.
2. Oxidizable organic matter which are chiefly non-nitrogenous.

1820.—*Give a table of bodies to be sought for and information to be elicited in the quantitative tests for the determination of organic matter and their products.*

The analysis may be considered under two heads.—

(A.) The determination of nitrogenous organic matters and their products,

(B.) The determination of oxidisable organic matter, probably chiefly non-nitrogenous.

(A) Includes—

(*a*) The determination of the free, saline or combined ammonia.
(*b*) „ of the solid albuminoid ammonia.
(*c*) „ of the nitric acid, existing as nitrates.
(*d*) „ of the nitrous acid existing as nitrates.

(B) Includes—

(*e*) The determination of the oxidisable organic matter by the permanganate process.

1821.—*What methods are had recourse to to demonstrate quantitatively the amount of organic matter in water?*

WANKLYN's ammonia process,
FRANKLAND's combustion process, and
FORCHAMMER's oxygen process.

[None of these profess to give the total amount of organic matter in water, but each fixes upon some one or more element, or compound, or property, which is determined with precision and taken as a measure or index of the total organic matter, to which it is assumed to bear a constant ratio.]

1822.—*What two distinct methods are employed in the determination of nitrogenous organic matters in water?*

1. WANKLYN's albuminoid ammonia, and free ammonia.
2. FRANKLAND's organic C. and organic N.

1823.—*How are the results expressed in figures?*

In grains per gallon, or in parts per 100,000, or in grammes per litre.

1824.—*How are grammes per litre, and milligrammes per litre converted into grains per gallon?*

Grammes per litre are converted into grains per gallon by multiplying by 70. Milligrammes per litre, if multiplied by ·07, are brought into grains per gallon. Grains per gallon are converted into parts per 100,000 by dividing by ·7; parts per 100,000 are brought into grains per gallon by multiplying by ·7.

1825.—*How may grains per gallon be converted into milligrammes per litre?*

By multiplying by 14·3.

1826.—*How may grains per gallon be converted into grammes per litre?*

By multiplying by ·0143.

1827.—*What solutions are essentially needed for the determination of the free and albuminoid ammonia?*

For this analysis we require—1. A standard solution of ammonium chloride, 1 C.C. of which = 0·01 of a milligramme of ammonia (NH_3); 2. Nessler's solution as a reagent for the detection of ammonia; 3. A solution of potassium permanganate and caustic potash; 4. Pure distilled water.

1828.—*How are the various solutions required for the determination of free and albuminoid ammonia prepared?*

(*a.*) *Ammonium Chloride Solution for Nesslerising.*

0·315 gramme of ammonium chloride in 1 litre of water. This is the *strong* solution.

Take 100 C.C. of this solution and dilute to 1 litre. This is the *standard* solution.

1 C.C.=0·01 milligramme of ammonia (NH_3) or 0·0082 mgm. of nitrogen.

(*b.*) *Nessler's Solution.*—Dissolve 35 grammes of potassium iodide in 100 C.C of distilled water. Dissolve 17 grammes of mercuric chloride in 300 C.C. of distilled water; warm if necessary, and allow to cool. Add the mercuric solution to the iodide solution until a perceptible permanent precipitate is produced. Then dilute with a 20 per cent. sodium hydrate solution (caustic soda) up to 1000 C.C. (1 litre): add mercuric chloride solution until a permanent precipitate again forms; allow precipitate to settle, and then decant off the clear solution.

(*c.*) *Sodium Carbonate* (sometimes required for free ammonia, but not usually needed.)—A 20 per cent. solution of recently ignited pure sodium carbonate.

(*d.*) *Alkaline Potassium Permanganate Solution* (for albuminoid ammonia).—Dissolve 200 grammes of potassium hydrate and 8 grammes of pure potassium permanganate in 1100 C.C. of distilled water, and boil the solution rapidly till concentrated to 1000 C.C.

(*e.*) *Distilled Water free from Ammonia.*—The S.P.A. recommend boiling ordinary distilled water with 1 per 1000 of pure ignited sodium carbonate. If the water is distilled with a little phosphoric acid (as recommended by Notter), it comes over quite free. Test with a little Nessler's solution.*

1829.—*What is the object of the carbonate of soda?*

To expel the free acid from any water which is acid. As a rule it is not necessary to employ it.

1830.—*How is the carbonate of soda solution prepared?*

A saturated solution of Na_2CO_3 may be prepared by boiling an excess of the common carbonate with water, and about 10 C.C. of the solid saturated nitrate of silver solution is the proper quantity to use in a water analysis. [Instead of solution the recently dessicated solid carbonate may be employed.]

1831.—*What is meant by "free ammonia"?*

The ammonia which is in combination with nitric, carbonic and other acids, or with other bodies which are readily decomposed.

1832.—*What is the test for ammonia?*

Nessler's solution to the water, and if ammonia is present it gives a yellow tint varying with the amount of ammonia present; even to a brick-red precipitate. This is also a quantitative test for NH_3.

This precipitate is quantitative by collecting and drying it. The precipitate of NH_3 is a distinct indication of animal decomposition, and water is therefore to be rejected. By experience we learn the amount of ammonia present from the degree of colouration produced in this reaction, although for exact analysis the quantitative method must be employed. If the ammonia is small in quantity, several inches in depth of water should be looked through on a white ground.

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*PARKES' *Practical Hygiene.*

1833.—*What is meant by "Nesslerising"?*

"Nesslerising" is a process by which the free or saline ammonia in a sample of water can be readily determined with great accuracy.

1834.—*Whvt matters are in use in the determination of nitrogenous organic matters?*

The albuminoid ammonia process of WANKYLN and the organic carbon and organic nitrogen processes of FRANKLAND.

1835.—*What are the principles of the* WANKLYN *process?*

1. That most of the injurious organic matter is contained in the nitrogenous organic matter, and (2) when nitrogenous organic matter is heated with a slightly alkaline solution of permanganate of potash, it gives off a certain proportion of its nitrogen as ammonia.

This is a great drawback, as the results of one process, though perfectly comparable in themselves, cannot be compared with the results of another process. There are three processes usually resorted to by water analysts: (*a*) The albuminoid ammonia processy (WANKLYN'S); (*b*) The permanganate process; (*c*) The organic carbon and organic nitrogen process (FRANKLAND'S).

1836.—*Upon what principle are these last mentioned processes based?*

None of these profess to give the total amount of organic matter in water, but each fixes upon some one or more element, or compound or property, which is determined with precision and taken as a measure or index of the total organic matter, to which it is assumed to bear a constant ratio.

1837.—*What proportion of actual nitrogenous matter does the ammonia evolved in this test represent?*

Only one-tenth.

1838.—*How is the carbonate of sodium solution prepared?*

It is a saturated solution of pure sodium carbonate.

1839.—*What apparatus and solutions are required for the estimation of organic matter as free and albuminoid ammonia?*

Apporatus, etc.—Retort (about one litre) and stand, burner, condenser, Nessler glasses, litre flask, measure, (25 C.C.) for permanganate solution, burette, pepette marked at 2 C.C. for Nessler's solution, standard solution of ammonia, permanganate of potassium solution, sodium carbonate solution, Nessler's solution, distilled water *free* from ammonia.

1840.—*What is the first precaution to be taken?*

Distil some pure water and reject the first portions of the distillate. It should be tested as to its freedom from ammonia with Nessler's reagent.

1841.—*Is the absence of free ammonia, or its presence in a very small amount, of importance in determining the organic purity of a water?*

Free ammonia, being absent, or very small, a water should not be condemned unless the albuminoid ammonia reaches something like 0·10 per million. Albuminoid ammonia above 0·10 per million begins to be a very suspicious sign, and over 0·15 it ought to condemn a water absolutely. The absence of chlorine, or the absence of more than one grain of chlorine per gallon, is a sign that the organic impurity is of vegetable rather than of animal origin; but it would be a great mistake to allow water highly contaminated with vegetable matter to be taken for domestic use.

In the albuminoid ammonia process a clean cylinder is taken, and into it is dropped a certain measured volume of the dilute standard solution of ammonia, and filled up with distilled water to 50 C.C. To this 2 C.C of Nessler's reagent is now added; if the colour produced is the same as that of the tested distillate, then the test is completed; the number of C.C. of ammonia solutions represents the ammonia or nitrogen in the distillate. If the two solutions are not of equal depth of colour, another standard one must be made up, and another comparison made until the colours are of the same depth Each 50 C.C of distillate after the addition of the permanganate must be tested until no colour is produced, and the amounts must be added together, the total represents the 'albuminoid ammonia'

1842.—*During the boiling process when does the NH_3 come off?*

About 75 per cent. of the "free ammonia" is evolved in the first 50 C.C. of the distillate. From this it follows that the whole amount need not be distilled, and that after the first 50 C.C. is given off, about one-third should be added to the result.

1843.—*What is the most generally employed quantitative test for ammonia?*

The method of WANKLYN and CHAPMAN is that generally adopted.

1844.—*What is the use of Nessler's reagent in water analysis?*

It is the most perfect qualitative and quantitative test for ammonia known.

The process is dependent on the use of the Nessler test in the estimation of ammonia, and on the fact that nitrogenous organic matter yields a definite quantity of its nitrogen, in the form of ammonia, on distillation with an alkaline solution of potassium permanganate.

1845.—*Is Nessler's solution a delicate test for ammonia?*

Yes; by it we are able to detect 1 part in 20,000,000. It is the most perfect test for ammonia known.

1846.—*What precaution is necessary with regard to the Nessler solution ?*

That it be clear, or at least not turbid. This requirement is fulfilled if the solution is freshly made and discarded when turbidity arises.

1847.—*How should the Nessler solution be kept ?*

The stock of Nessler solution should be kept in a well stoppered bottle from which a little is poured out from time to time as it is required.

1848.—*What are the characters of Nessler's solution ?*

Properly made the Nessler's reagent has a slightly yellowish tint; if quite white it is certain not to be sensitive and requires further addition of corrosive sublimate. It should be tested before being used. This is done by taking about 2 C C. of the solution and adding to it a few drops of a very weak solution of ammonia (of about ·05 milligramme of ammonia in 50 C.C. of water), and if it be in proper condition it will at once strike a yellowish-brown hue with the solution.

1849.—*In a qualitative analysis when is the NH_3 looked for ?*

During two periods, before and after adding the alkaline permanganate solution.

1850.—*What is the ammonia called at each of the stages respectively ?*

(1) Free or saline ammonia; (2) Abuminoid ammonia.

1851.—*What apparatus and solution are required for the ammonia process ?*

The Nessler reagent.
Standard ammonia chloride solution.
Solution of $KMnO_4$ and caustic potash.
Carbonate of soda (sometimes).
Distilled water absolutely free from ammonia.
Retort.
Liebeg's condenser.
Lamp and retort holder.
Glass cylinders which shall contain about 160 C.C. for Nessler's test, are graduated at 100 C.C. and at 150 C.C.
Nessler glasses.
Half litre flask.
Measure for solution of potassium permanganate.
Graduated burette.
Pipette for Nessler's reagent, which should be marked off at 2 C.C.
Bottles, etc.

1852.—*How is the standard ammonia chloride solution prepared?*

Ammonium chloride ·3146 grm., pure distilled water 1 litre. Each C.C. contains ·0001 grm. of ammonia, that is one-tenth of a milligramme.

1853.—*What is the principle of the Nessler test for ammonia?*

The Nessler test is based on the fact, that when a saturated solution of iodide of mercury in iodide of potassium, rendered strongly alkaline by the addition of caustic potash, is added to water containing ammonia, various shades of a brown colour are produced. By comparing these shades of colour with those produced in standard solutions of ammonia, the amount of ammonia present in the sample of water under examination may be estimated. It is necessary that the ammonia solution be very dilute; for, if too strong, the reagent will be either precipitated, or the delicate shades of colour, so necessary for the success of the test, destroyed by the intense dark colour produced. In testing ordinary water, it is necessary to concentrate the water by distillation; but in the case of sewage, which is always rich in that substance, pure distilled water, free from ammonia, must be added to the distillate till the proper degree of dilution is obtained.

By the Nessler test we are able to measure the nitrogenous organic matter in waters by the quantity of ammonia yielded as a result of the destruction of the organic matters, the delicate Nessler's solution showing accurately the amount of ammonia, the destruction of the organic matter being effected by potassium permanganate in an enormous excess of caustic potash, the destruction being effected at the boiling point.

1854.—*What is the object aimed at in comparing the distillate with that of the standards of distilled water, ammonia chloride, and Nessler's solution?*

The object is to make a solution of known strength equal in colour to the unknown. The two tubes when examined should be placed side by side, their ends resting on a white porcelain slab or sheet of white paper. If they differ, another experiment must be made, more or less of the standard ammonia solution being used as judged necessary. When the shade of colour in both tubes is alike, the amount of ammonia present may be calculated out. The other three tubes may in turn be Nesslerised, and the amounts of ammonia found added together, but in most cases it will be sufficient to add a third to the amount present in the first 50 C.C. collected.

1855.—*How is Nessler's solution prepared?*

Thirty-five grms. of potassic iodide are dissolved in 100 C.C. of water, 17 grms. of pure mercuric chloride are boiled in 300 C.C. of water and then cooled. The mercuric solution is added little by little, to the potassium iodide, until a permanent precipitate is formed.

The liquid is now made up to a litre, with a solution of sodic hydrate (strength, 20 per cent.). Lastly, the reagent is made more sensitive by the final addition of a little more of the mercuric chloride solution, until a permanent precipitate begins to form. The solution is put on one side to deposit, and the clear liquid decanted for use.

1856.—*How is the quantitative test for free ammonia carried out?*

Place in a retort 250 C.C. of the water to be examined. Attach the retort to a Liebeg's condenser, and distil off about 130 C.C.; collect 1 C.C. more of the distillate, and test it with a few drops of Nessler to see if any ammonia is still coming over; if so, the distillation may be continued longer. Carefully measure the amount of distillate; test a little with Nessler's solution in a test-tube; and, if the colour be not too dark, take 100 C.C. of the distillate and put it into a cylindrical glass vessel, placed upon a piece of white paper. Add to it 1½ C.C. of Nessler. Pour into another similar cylinder as many C.Cs. of the standard ammonium chloride solution as may be thought necessary (practice soon shows the amount), and fill up to 100 C.C. with pure distilled water: drop in 1½ C.C. of Nessler. If the colours correspond after three to five minutes, the process is finished, and the amount of ammonium chloride used is read off. If the colours are not the same, add a little more ammonium chloride so long as no haze shows itself; if it does, then a fresh glass must be taken, and another trial made. When the process is completed read off the number of C.C. of ammonium chloride used, allow for the portion of distillate not used, multiply by 0·01 and then by 4: the result is milligrammes of free ammonia per litre, or parts per million; dividing by 10 gives parts per 100,000; multiply the latter by 0·7 to bring to grains per gallon.*

1857.—*What precautions are necessary in applying the test?*

Should the colour of the distillate prove too dark, a smaller quantity may be used, and made up to 100 C.C., with distilled water. WANKLYN recommends, distilling only 50 C.C., Nesslerising it, and then adding one-third to the result, on the ground that (as he says) two-thirds of the ammonia come off in the first 50 C.C. He also states that with smaller sized apparatus 100 C.C. of water gives satisfactory results. The Society of Public Analysts recommends successive portions being distilled over and Nesslerised until ammonia ceases to appear. Practically the whole of the ammonia comes over in the first 130 C.C., or nearly so.

The use of permanent coloured solutions, corresponding with known amounts of ammonia has been recommended, and caramel has been tried at Netley, but the results have not been very satisfactory. A colorimeter may be used if preferred.

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*PARKES' *Practical Hygiene*, 7th Ed.

When a Liebeg's condenser cannot be obtained, a flask may be used instead of a retort, and the distillate conveyed to the receiver by a tube of glass (or block tin) passing through a vessel of cold water, which must be renewed from time to time. The tube may be bent in any convenient way, so as to expose it to the cooling water as much as possible. Every part of the apparatus must be scrupulously clean and well washed with distilled water previous to commencing the experiment. The S.P.A. recommend that the retort tube should be packed into the condensing tube by means of an India-rubber ring; or it may be done with clean writing-paper, as WANKLYN proposes. In either case the substance used must be quite clean. It is well to wash the retort, flask, and glass tubes with dilute sulphuric acid, and then rinse them out clean with distilled water. In distilling, the retort should be thrust well into the flame, and the distillation carried on rapidly. If the water is very soft, the addition of a little pure or recently heated sodium carbonate may be made, but in ordinary circumstances it is not necessary and is not advisable *

1858.—*Give an example of the working of this estimate.*

Suppose that from 250 C.C. of water 133 were distilled; 100 C.C. were taken for the experiment; 4·5 C.C. of ammonium chloride solution were required to give the proper colour; then $4·5 \times \frac{133}{100} \times 0·01 \times 4 = 0·2394$ milligrammes of free ammonia per litre; $0·2394 \div 10 = 0·02394$ per 100,000.

1859.—*How do we get the factor* ·01 ?

The standard solution contains ·0315 gramme NHCl in a litre of distilled water ascertained to be free from ammonia, so that the litre comes to ·01 gramme of ammonia and each C.C. to ·00001 grammes, the equivalents of NH_4Cl and NH_3 being 53·5 and 17, or in the ratio of 0315 to 01.

1860.—*What is* Professor NOTTER's *recommendation with regard to the condition of the distilled water used for the comparison?*

That distilled water for making up standards of ammonia must be very pure, and should be distilled with a little phosphoric acid to fix the ammonia.

1861.—*What effect has Nessler's solution on liquids containing ammonia or salts of ammonia?*

When added to such a solution (even if the ammonia present be very small in quantity) a light yellow, a dark yellow, or a brown colouration is produced according to the quantity of ammonia present. If there is a very large quantity of the ammonia in the liquid a precipitate is formed.

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* PARKES' *Practical Hygiene*, 7th Ed.

1862.—*What is the precipitate?*

It is a salt named hydrargyro-ammonium iodide (Hg_2NIH_2O), or tetra-mercur-ammonium or ammonium in which four atoms of hydrogen are displaced by two of mercury.

1863.—*Is it a delicate test for ammonium or its salts?*

Yes; the most delicate test that is known. It is capable of detecting one-hundredth of a milligramme of ammonium in two litres of water; or one part in 200,000,000 parts if the water be condensed to one litre.

1864.—*What does the "free" or "saline ammonia" represent?*

The "free" or "saline ammonia" represents the ammonia combined with carbonic, nitric, or other acids, and also what may be derived from urea, or other easily decomposable substances, if they are present. The limit in good waters is taken at 0·002 centigrammes per litre; in bad waters it often reaches 100 times this and more. [After the distillation of the free ammonia, the residue of the water in the retort is used for determining the *albuminoid ammonia*, to be now described.]

1865.—*What is Nessler's solution chemically?*

It is a watery solution of potassium iodide, saturated with hydrargyri biniodidi, made strongly alkaline with hydrate of potassium.

1866.—*What are the chemical reactions occurring in the preparation of Nessler's solution?*

Thirty-five grammes of iodide of potassium are dissolved in a small quantity of distilled water; a saturated solution of corrosive sublimate is then added in small quantities at a time, a red precipitate takes place which is dissolved almost at once. On adding more of the Hg_2Cl_2 solution a point is reached when the precipitate no longer dissolves. Enough of the Hg_2Cl_2 solution has then been added. The solution is filtered and 160 grammes of KOH or 120 of NaOH is added in strong watery solution. The liquid is then made up to a litre by adding distilled water. Lastly 5 C.C. of a saturated solution of $Hg_2Cl._2$ is added. This gives clearness to the solution and renders it very sensitive to the reactions for which it is used. The liquid is allowed to stand and a sediment is deposited and the clear liquid is decanted into a large bottle with a well-fitting glass stopper. From this stock bottle the solution may be removed as occasion arises for it, as frequent opening the stopper renders the liquid turbid.

1867.—*What modifications are to be adopted in analysing very bad waters?*

In analysing very bad waters it will be found that in the course of the distillation the 5 C.C. of permanganate solution are exhausted. When this happens another 5 C.C. of permanganate must be dropped into the retort, and the operation continued, care being taken to leave an excess of permanganate before the stage is reached at which sulphuric acid is added.

1868.—*What are the advantages of the ammonia process?*

It is simple, accurate, easily carried out, the information it gives is definite. [By it we are able to detect 1 part of albuminoid ammonia in 10,000,000.]

The ammonia process is practically a combustion process carried on in water; the ammonia being the ultimate product of combustion.

Advantage of the ammonia process over the organic nitrogen and organic carbon process is that it operates in the water itself and not in the dry residue.

1869.—*When the ammonia is in great excess in the water what happens?*

The colour produced is too deep to be accurately read off.

1870.—*What should then be done?*

The simplest way to overcome the difficulty is to dilute the water with ten times its bulk of distilled water and submit 50 C.C. of this dilution to the Nessler process.

1871.—*How might a beginner in such analytical processes test the accuracy of his work?*

A water containing a known quantity of nitrogenous organic matter may be prepared artificially and then the ammonia process may be applied to it and the actual analytical results compared with the calculated result. Having prepared an artificially polluted water of known degree of pollution, let the ammonia process be worked and let the analyst judge how far he may trust his work by the degree of correspondence between the experimental and the calculated results.

1872.—*What occurs if the ammonia be in excess?*

A precipitate takes place at once.

1873.—*What is the precipitate and what is its chemical formula?*

It is the hydrargyro-ammonium iodide or iodide of tetra-mercur-ammonium, or ammonia in which four atoms of hydrogen are displaced by two of mercury. The formula Hg_2NIH_2O.

1874.—*How may the amount of ammonia be calculated from the amount of precipitate?*

By multiplying the precipitate by ·03041.

1875.—*Whence is the ammonia in the water usually derived?*

Free ammonia is derived from urea. Urea is only found in water recently contaminated, for it is rapidly converted into carbonate of ammonia.

1876.—*What is the limit of free ammonia in a good water?*

From *nil* or ·001 to ·003 per 100,000 parts, and very rarely does it reach ·005.

1877.—*When should the estimation of the ammonia be commenced?*

It is desirable to proceed at once with the determination of this constituent, since it is the most liable to change. The method of estimation is based upon the fact that an alkaline solution of mercuric iodide, added to a liquid containing ammonia, produces a brown colouration, due to the formation of the iodide tetra-mercurammonium. This test, known as Nessler's, is capable of detecting one part of ammonia in 20,000,000 parts of water.

1878.—*Why is it necessary to commence the ammonia process as soon after receiving the sample of water as possible?*

Because the ammonia is the constituent most liable to undergo change, or oxidation, combining with alkaline bases especially those of sodium and potassium, to form nitrites and nitrates.

1879.—*In what waters is ammonia found?*

Most kinds of water contain ammonia, or ammoniacal salts, which either was recently, or may presently become, a constituent of organic matter. In addition to this, most kinds of water actually do contain more or less nitrogenous organic matter, which furnishes ammonia either on simple boiling with carbonate of soda, or else on boiling with permanganate of potash, in presence of excess of alkali. By estimating the amount of ammonia obtainable from water, noting the circumstances under which it is obtained, we have a measure of the nitrogenous organic matter present in water.

1880.—*What is the value of the information acquired by ascertaining the amount of free ammonia in water?*

The presence of NH_3 is a quite sure indication of recent contamination with decaying organic matter capable of yielding NH_3, whether in spring, stream or wells. This readily oxidises and is thus converted into nitrous acid, and by longer exposure into nitric acid. These acids combine freely with a lime or other alkaline base as nitrate and nitrite of lime. Many analysts attach great importance to the value of the nitrates and nitrites present, as indications of the nature of the contaminations of the water.

1881.—*What is the sanitary importance of ammonia found in air and water?*

It derives its sanitary importance from its presence and amount giving a fair estimate of the purity of these essentials of life. Whenever moist, nitrogenous matters decompose, ammonia is one of the products. It is found in minute quantities in even good air and water. It is likewise found in clayey and peat soils. The greater the degree of injurious pollution of air and water, the larger, as a rule, is the amount of ammonia present. It is probable that of the disgusting odours from drains, etc., are really stinking ammonias.

Animal and vegetable matters contain nitrogen spoken of as organic nitrogen (FRANKLAND and ARMSTRONG). It is also contained in NH_3, and ammonium salts, and these are due entirely to the decomposition of nitrogenous vegetable and animal matters. For this reason, NH_3, although itself harmless, is determined quantitatively. The amount even in polluted water is small. It is however significant of organic pollution: ·1 part per 100,000 is grossly polluted water. Nitrates and nitrites are themselves harmless, but are the result of oxidation of nitrogenous organic matter.

1882.—*What is the indication of ammonia in the absence of chlorine nitrites and nitrates?*

Ammonia, without nitrates and nitrites and chlorine, indicates vegetable contamination; with them, probably animal. Changes in the relative proportion of nitrates and nitrites show the presence of bacteria, some of which exert a reducing action, and others the opposite, according to circumstances.

1883.—*What does this fact indicate?*

That ammonia will be found in all sewage polluted waters, unless the sewage has been filtered through a sufficient thickness of soil to convert the ammonia by oxidation into nitrates and nitrites.

Ammonia in almost every quantity is to be deprecated, since it is the result of decomposition of animal and vegetable substances, and has the qualities which are not beneficial as food.

1884.—*What does ammonia in water point to?*

Naturally water (even rain water) contains it in small quantities, but if there be much, and there is considerably an absence of HNO_2, HNO_3 or chlorine, it is probable that NH_3 is derived from vegetable organic matter undergoing decomposition, (as in marsh water). If in an ordinary condition of water there is more than ·08 parts per 1000, it probably arises from the recent conversion of urea into ammonium carbonate (corroborated by the co-existence of abundance of "chlorine").

1885.—*How much free and albuminoid ammonia are allowable in drinking waters?*

Pure waters yield from *nil* to 0·002 parts per 100,000 of free ammonia, and from *nil* to 0·005 per 100,000 of albuminoid ammonia. Usable water may contain up to 0·005 per 100,000 of free, and 0·01 per 100,000 of albuminoid ammonia. These numbers, however, require qualification, for they may be exceeded in cases where water is thoroughly good for dietetic purposes. Rain water often contains a large amount of free ammonia, probably derived from soot, and it then appears to be harmless.

1886.—*What is* SCHULTZ' *permanganate of potash test for organic matter in water?*

In order to avoid some of the fallacies and inconveniences of the test with acid, F. SCHULTZ tried the following plan, which was slightly modified by LEX. Five or more vessels, each containing 60 C.C. of the water to be examined, are taken, and to each 2 C.C. of thin milk of lime are added, and then 1, 2, 3, 4, 5, etc., C.C. of the permanganate solution (·395 gramme per litre) are added, and left for three hours. At the end of that time some of the samples will be decolorised, others still coloured; if No. 1 and No. 2 are colourless, and No. 3 is coloured, then the amount of permanganate destroyed is between 2 and 3 C.C. As in the cold each equivalent of permanganate only gives off 3 (not 5 atoms) of oxygen, each C.C. corresponds, not to ·1, but to ·06 milligrammes of oxygen. It is for this reason that 60 C.C. of water are taken instead of 100, for it is evident that if 1 C.C. of the permanganate solution gives only ·06 milligrammes to 60 C.C. it is the same as ·1 to 100 C.C. of the water. The calculation of the results is thus easy; if, for example, Nos. 1 and 2 are declorised, while No. 3 is coloured, the amount of oxygen required is between ·2 and ·3 milligrammes for 100 C.C., or 2 and 3 per litre. If 60 C.C. of a water take less than 3 C.C. of the permanganate solution to give it a colour permanent for two hours, it is a good water (according to LEX) so far as this test is concerned; if 3 and 4 C.C. are required it is a medium water, and if the 5 C.C. do not give a colour the water is bad.

1887.—*How is the "albuminoid ammonia" process carried out?*

25 C.C. of the solution of alkaline permanganate are added to the residue in the retort, after the distillation of the free ammonia, and about 110 to 120 C.C. distilled off. It is sometimes convenient to add a little pure distilled water to the residue if the first distillation has been carried rather far. WANKLYN recommends successive quantities of 50 C.C. to be distilled off and tested until no more ammonia comes over. Determine the amount of ammonia, as was done in the case of the free ammonia, and state the results in this case as *albuminoid ammonia*. In this distillation there is sometimes a little difficulty caused by "bumping," especially in the case of bad waters; to remedy this it has been recommended to use pieces of tobacco pipe which have been heated to redness immediately before use. It is better, however, to dilute the water if it be a bad one, and not to distil too rapidly.

1888.—*In this test how is the albuminoid ammonia expressed?*

As so much *free ammonia*, because the alkaline permanganate solution disintegrates the nitrogenous organic matter, and sets free the ammonia, which is (as in the ordinary quantitative test for ammonia) volatilised and calculated in the same way as the free ammonia itself. [This is known as WANKLYN's "Alkaline permanganate" method.]

1889.—*What is the object of the albuminoid ammonia process?*

The object of this process is to get a measure of the nitrogenous organic matter in water by breaking it up and converting the nitrogen into ammonia by means of potassium permanganate in the presence of an alkali; the ammonia can be distilled off and estimated as above. It is to be understood that this does not deal with all the nitrogenous matter, but the results are sufficiently uniform to be useful. According to WANKLYN and CHAPMAN, the albuminoid ammonia multiplied by 10 gives a fair approximate estimate of the nitrogenous matter in water.

1890.—*Is the absence of albuminoid ammonia in water of importance in coming to a conclusion as to its organic purity?*

If a water yield 0·00 parts of albuminoid ammonia per million, it may be passed as organically pure, despite of much free ammonia and chlorides; and if indeed the albuminoid ammonia amount to ·02, or to less than 0·05 parts per million, the water belongs to the class of very pure water. When the albuminoid ammonia amounts to ·05, then the proportion of free ammonia becomes an element in the calculation, and we should be inclined to regard with some suspicion a water yielding a considerable quantity of free ammonia, along with more than ·05 parts of albuminoid ammonia per million.

The presence of a considerable amount of albuminoid ammonia, with little free ammonia and chlorides, is generally indicative of vegetable organic matter, often peaty. This is the character of the greater part of the water-supply of Ireland.

The real significance of the albuminoid ammonia has been much discussed, but the results obtained are sufficiently uniform to give us a convenient measure of purity, provided we are careful not to draw the line too close. All the nitrogen of the organic matter is certainly not obtained by this method, but this is immaterial so long as the proportion is fairly maintained. The results correspond to a certain extent with the *organic nitrogen* of FRANKLAND, and the process is much more feasible for medical officers generally.

1891.—*What does albuminoid ammonia in water point to?*

Naturally water (even rain water) contains it in small quantities, but if there be much and there is coincidently an absence of HNO_2 or HNO_3 or chlorine, it is probable that the NH_3 is derived from vegetable organic matter undergoing decomposition (as in marsh water). If in an ordinary water there is more than ·08 parts per 100,000, it probably arises from the recent conversion of urea into ammonia (corroborated by the co-existence of abundance of "chlorine").

Absence of any trace of albuminoid ammonia is suggestive of organic purity, even if free ammonia and chlorides are high. Albuminoid ammonia less than ·05 part per million is consistent with extreme purity; and if free ammonia is absent or scanty, albuminoid ammonia under 0·10 is no evidence of impurity. If, however, there is much free ammonia, 0·05 albuminoid ammonia is suspicious, and 0·10 is strong evidence of pollution; 0·15 or more should condemn a water absolutely.

In good waters the free ammonia usually ranges from 0·00 or 0·01 to 0·03 part per million, and rarely exceeds 0·05.

These general rules are subject to some modification according to the history and surroundings of the water, which should always be studied. Vegetable is much less dangerous than animal contamination, and may often be recognised by the slowness with which the albuminoid ammonia comes over, by the absence or small amount of chlorides and of free ammonia, and by microscopic examination of the sediment or knowledge of the course of the supply. Animal pollution is indicated if the albuminoid ammonia comes over rapidly, or if the chlorides or oxidised nitrogen are abundant. Pollution by absorption of effluvia, or by the presence of putrefying masses in the water would, however, be unaccompanied by any excess of chlorides.

1892.—*What is the relation between ammonia and sewage contaminated water?*

The urea of the urine by a process of fermentative decomposition rapidly becomes carbonate of ammonia in sewage. Ammonia will, therefore, be found in all sewage polluted waters unless the sewage has been filtered through a sufficient thickness of soil to convert the ammonia by oxidation into nitrates and nitrites. A few pure deep well waters from the chalk and greensand are found to contain excess of ammonia, but they are remarkably free from organic matters. On the other hand sewage polluted shallow well waters which contain excess of ammonia contain also an excessive amount of organic matters.

1893.—*What does the absence of albuminoid ammonia indicate?*

It is suggestive of purity as regards organic matter, and this holds good even if the ammonia (saline) and chlorides are in moderate quantities.

1894.—*What are the indications of varying quantities of albuminoid ammonia?*

Albuminoid ammonia less than ·05 part per million is consistent with extreme purity; and if free ammonia is absent or scanty, albuminoid ammonia under 0·10 is no evidence of impurity. If, however, there is much free ammonia, 0·05 albuminoid ammonia is suspicious, and 0·10 is strong evidence of pollution; 0·15 or more should condemn a water absolutely.

1895.—*How much albuminoid ammonia is found in the English lakes?*

As to the English lakes, it was only 0·001 in 100,000 parts in Grassmere and Derwent water; 0·002 in Rydal Lake and Windermere, 0·004 in Buttermere, and 0·007 in Crunock water.

1896.—*What does considerable quantity of albuminoid ammonia with little free ammonia indicate?*

That the impurity is chiefly of vegetable origin, and if chlorine is also absent, or only in very small quantity, it is almost certain that the albuminoid ammonia is of vegetable origin.

1897.—*If albuminoid ammonia co-exist with free ammonia chlorine and nitrates, what does it show?*

That the impurity is of animal origin (probably sewage) and therefore of a most dangerous nature.

1898.—*What does much albuminoid ammonia with little ammonia and absence of chlorides show?*

Contamination by vegetable matter.

1899.—*What quantity of albuminoid ammonia is sufficient to condemn a water?*

With ·15 parts *per* 1000,000 we should absolutely condemn the water.

„ ·10 „ „ „ we should consider it suspicious.
„ ·02 to ·05 „ „ „ „ pure,
„ ·00 „ „ „ „ the purest water.

1900.—*Which is the more dangerous in a water, nitrates or albuminoid ammonia?*

The latter, because it is three stages nearer the original source of contamination—probably sewage.

1901.—*What quantities of free and albuminoid ammonia would lead you to condemn a water?*

The water should be rejected if it contains 0·15 parts of albuminoid ammonia per million. Water with free ammonia 00·1, albuminoid ammonia 0·04, may be passed as a pure water. Free ammonia, however, being absent, or very small, water should not be condemned unless the albuminoid ammonia reaches something like 0·10 per million (WANKLYN).

Good water should not contain more than ·08 milligrammes per litre. Albuminoid ammonia is chiefly derived from animal matter, but according to PARKES, decaying leaves and peat may also produce it. Much albuminoid ammonia, with little free ammonia and no chlorides means vegetable contamination (J. C. BATTERSLY).

1902.—*How much nitrogen would be contained in ammonium nitrate, sodium nitrite, and urea?*

$(NH_4) NO_2$ . . .	·50 gramme.
$NaNO_3$ . . .	·37 ,,
CH_4N_2O . . .	·15 ,,

Knowing the formula and the atomicities of the elements contained, the finding of the amount of any one element in a certain quantity of a compound is a mere matter of simple proportion.

1903.—*What are the relations of ammonia, nitrates, and nitrites in water?*

Ammonia is almost always present in very small quantity, but if it be in large enough amount to be detected without distillation, it is suspicious. If nitrates, etc., be also present, it is likely to be from animal substances, excreta, etc. Nitrates and nitrites indicate previously existing organic matters, probably animal, such as excreta, remains of animals, etc.; but nitrates may also arise from vegetable matter, although this is probably less usual. If nitrites largely exist, it is generally supposed that the contamination is recent. The coincidence of easily oxidised organic matters, of ammonia, and of chlorine in some quantity, would be in favour of an animal origin. If a water gives the test of nitric acid, but not nitrous acid, and very little ammonia, either potassium, sodium, or calcium nitrate is present, derived from soil impregnated with animal substances at some anterior date.

1904.—*What is the chief origin of the ammonia of sewage?*

The urea of the urine which by a process of fermentative decomposition rapidly becomes carbonate of ammonia in the sewage.

1905.—*Discuss in general terms the ammonia process of* WANKLYN, *and* FANKLAND *and* ARMSTRONG'S *organic nitrogen process.*

It is customary to determine the amount of ammonia and of nitrogen which exists in the form of nitrites and nitrates, not because these compounds are likely to exist in quantity sufficient to work harm of themselves, but because they are the result of the decay or decomposition of nitrogenous organic matter. As a rule, the amount that occurs in unpolluted water is very small, and even in polluted waters it is small when expressed in figures. The ammonia can without difficulty be determined when present, even in minute quantity.

The second general method in anything like common use is a method devised by FRANKLAND and ARMSTRONG; it was used in the great number of examinations published in the reports of the Rivers Pollution Commission of Great Britain. The method consists in evaporating a given quantity of the water, under carefully regulated conditions, and on submitting the residue to a process of organic analysis, by which all the carbon is converted into carbonic acid and the nitrogen is liberated in the gaseous state. The mixture of nitrogen and carbonic acid is then analyzed by processes of gas analysis. The results are stated in so many parts of "organic carbon" and so much "organic nitrogen" in 100,000 parts of the water, and sometimes the two amounts together are spoken of as the amount of the "organic elements."

As a chemical process, this method has been made the subject of much criticism by its opponents; from this point of view we can hardly discuss the matter appropriately. As at present employed, in the hands of competent persons, it is calculated to give good results; but the great question is, of how much value are the results when obtained? The process, in the words of the originator, is "both troublesome and tedious," and requires considerable manipulative skill, the apparatus employed is somewhat costly and frangible, and a good deal of time is unavoidably consumed in the examination.

It is true that, if we have the amount of organic nitrogen and carbon, we come nearer to having the amount of organic matter than is possible by any other means; but, as has been already said, it is, after all, not the amount, but the character, which is to be considered and which is so important. In this method of analysis, the character and probable origin are inferred from the relative proportion of carbon and nitrogen. Thus, in waters which were rendered impure by the presence of extract of peat; the average amount of nitrogen was to the amount of carbon as 1 · 11·9, while the proportion in sewage was as 1 : 1 8.

With reference to Frankland's method Sander says: "Without a knowledge of the previous history of the water, the relative proportion (between carbon and nitrogen) is not available as a means of deciding as to the nature of the contamination; if, however, the previous history of a water is known, there is scarcely need of so particular an analysis in order to judge of its character." For this reason Frankland's method has not been used to any extent in Germany or in this country.

CHAPTER XXIII.

Examination of Water—*continued.*

Hardness of Water.

1906.—*What means may be adopted to soften water?*

Lime may be added; soap may be used; or carbonate of soda may be employed; and on a small scale boiling may be resorted to.

1907.—*What simple domestic plan is often employed to soften water?*

Putting a marble into the kettle; this during the boiling, rolls about in the water and helps to drive off the excess of CO_2.

1908.—*What is meant by the term "hard" as applied to water?*

A *hard* water is one with which soap does not at once form a lather, but produces instead, a deposit of a curdy nature. Hard water presents a peculiar roughness to the touch. The hardness of unboiled water is called *total* hardness, while that of boiled water is called *permanent* hardness.

1909.—*How may we classify the kinds of hardness of water?*

TOTAL { *Temporary*, removed by boiling.
Fixed not affected by boiling.

1910.—*What is meant by permanent and temporary hardness of water?*

The *permanent* hardness is that not removed by boiling. It is called *permanent hardness* to distinguish it from the *temporary hardness* of water, which is removable by boiling.

[Natural waters contain varying proportions of lime and other mineral salts, and on the amount of these constituents depends the relative hardness or softness of water. The hardness of water is mainly due to the presence of the salts of lime and magnesia. When these are present in excessive quantity, the water is said to be "hard." A great destruction of soap also occurs when such water is used for washing clothes and other purposes.

A "soft water" is one below six degrees of hardness, and "each degree of hardness destroys $2\frac{1}{4}$ ounces of soap in each 100 gallons of water used for washing. Soft water is commercially of more value than hard water in proportion to the worth of 5 ounces of soap to each 200 gallons for each degree of hardness."

The hardness called "temporary" is caused by the presence of carbonates of lime and magnesia held in solution by an excess of carbonic acid. When the water is boiled, carbonic anhydride escapes, and the insoluble carbonates are precipitated, leaving the water so much softer, but causing a deposit or fur on the sides of the vessel. This fur is always inconvenient, often productive of great loss of heat, and is sometimes the cause of disastrous boiler explosions, owing to the superheating of the iron plates beneath the crust.

It is manifest that if these lime and magnesia salts could be removed before the soap is added, or the fur deposited before the water is put into the boiler, much inconvenience and expense would be avoided.

This can be done, as far as the salts causing temporary hardness are concerned, by means of a process invented by the late Dr. CLARK, of Aberdeen, which depends on the fact that when lime comes in contact with carbonate of lime and magnesia held in solution by excess of carbonic acid, the lime unites with the excess of carbonic acid, forming carbonate of lime, and the insoluble carbonate thus formed, together with the carbonates of lime and magnesia which are thrown out of solution by the abstraction of their solvent, is deposited. This operation is attended with but little trouble or expense, and not only improves the value of a water economically, but often increases and never diminishes its value for dietetic purposes.

The soap-destroying measure of hard water is called the "total hardness"; but many waters become softer on boiling. The decrease produced by boiling is called "temporary hardness," whilst the remaining hardness is termed "permanent" The permanent hardness is ascertained by first boiling some of the water gently, allowing the steam to escape freely, and then, after it has cooled and the loss by evaporation has been made up with recently boiled distilled water, applying to it the soap test as before*

1911—*How is the hardness expressed?*

It is customary to express the hardness in 'degrees'; and each degree of CLARK's scale indicates one grain of calcium carbonate per gallon of water, or the equivalent of one grain of chalk in soap-destroying power Thus, *e.g*, one degree of hardnesss may be due to one grain of calcium carbonate, 1·11 grain of calcium chloride, or 1·36 grain of calcium sulphate, etc, each of these calcium compounds containing in the above quantities respectively, 0·4 grain of calcium.

In France each degree of hardness indicates one part by weight of calcium carbonate, or its equivalent, per 100,000 parts of water; whilst in Germany a degree of hardness indicates one part of lime (CaO), or its equivalent, per 100,000 parts of water. Hence the various values of degrees of hardness are—English 1°= German 0°·8=French 1°·4 nearly. Many analysts who give the results of their analyses in parts per 100,000, use the French scale of hardness.

In England the actual hardness of water is spoken of as so many "degrees," each degree corresponding to the amount of soap that is destroyed by a certain quantity of the water. Fourteen degrees of hardness is the allowable limit in waters used for drinking and cooking purposes.

Scales pointing out the degree of hardness or softness are arbitrary. CLARK's standard is the one usually employed. Each degree of it corresponds with one grain of carbonate of lime to the gallon. FRANKLAND's is equally correct and easier to work. Any water below 6° is considered soft; any above this is said to be hard. A soft water contains from 4 to 9 grains of carbonate of lime and magnesia to the gallon, while a hard one contains from 9 to 40.

1912.—*What effect has the addition of lime to hard water?*

By the addition of lime (CaO) to the water, the lime in solution combines with the excess of carbonic acid that holds the salts in solution, and throws down the carbonate as a fine precipitate, and this, as it settles, also carries down suspended matters. Hence, not only does this plan soften the water, but it also frees it from suspended matters ; it has no effect on the sulphates and chlorides.

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* HEHIR's *Hygiene of Water and Water-Supplies.*

[The addition of *lime water* removes any considerable degree of hardness. It combines with the carbonic acid, and causes the formation of additional quantities of carbonate of lime, and this latter and all the previously contained carbonate of lime are precipitated.* It also causes the deposit of all suspended organic matter and much of the dissolved organic matter. It does not affect those salts giving rise to permanent hardness in water. It appears to act favourably in arresting organisms. The use of lime water is carried out extensively in a few places in England to reduce hardness.]

1913.—*What chemical reaction takes place on the addition of lime to water?*

Calcium bicarbonate and calcium oxide combine to form calcium carbonate *and* calcium carbonate.

1914.—*Discuss the question of removable and permanent hardness of water.*

The hardness due to carbonates of lime and magnesium is to a large extent removed by boiling; whilst the water, the hardness of which is but slightly, if at all, affected, contains *sulphate of lime*. Chalk waters are most influenced by boiling, as the carbonate of lime is held in solution by the excess of carbonic acid present. When a chalk water is boiled, the carbonic acid is expelled, and the carbonate of lime is to a great extent precipitated. The hardness, due to carbonate of lime, is termed 'temporary,' as it can be thus removed ; that due to the sulphates of lime and magnesia is termed 'permanent,' as it is not removable by boiling. It is always desirable to know to which of the above the 'hardness of water' is due, as, in excessive cases, a knowledge of the cause would determine whether the water might be rendered fit for domestic purposes.

1915.—*What is* CLARK's *process for reducing the hardness of water?*

Hard waters may be softened upon the large scale in reservoirs, by adding quicklime to the water. The lime and calcic bicarbonate react to form insoluble calcic carbonate, and this carries down with it suspended matters. A similar process may be employed on the domestic scale, using lime or washing-soda, or both.

1916—*What is the rationale of* CLARK's *quantitative test for hardness?*

When an alkaline oleate is mixed with pure water, a lather is formed; but if lime, magnesia, iron, alumina, etc., be present, more of the oleate in varying quantities will be required to form a lather.

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* AUTHOR's *Hygiene of Water and Water-Supplies* (Madras, 1891).

It is well known that hard water causes soap to curd and prevents the formation of a lather, until a large quantity of soap has been added. This fact has also been used as a measure of hardness, for it has been found that 2 lbs. of the best hard soap must be added to 10,000 gallons of water of 1° of hardness before a lather will remain, and hence that quantity used in 10,000 gallons or 1·2 lbs. in 1,000 gallons, or 0·12 lbs. in 100 gallons, to produce an ordinary lather is a measure of 1 degree of hardness.

1917.—*What is a soap?*

A soap is the combination of an alkaline base with a fatty acid.

In using soap for investigating it is necessary to produce a lather of the soap with the water. In hard water the blue acid of the soap combines with the lime or magnesium salt of the water and forms an insoluble curdy precipitate, and all the Ca or Mg must combine with the soap in this way before a lather will form. CLARK ascertained by experiment how many measures of a standard solution of soap were required by a gallon of distilled and other waters in order to form a lather.

Unfortunately an incorrect mode of registering the results was adopted, and a certain degree of confusion crept into the matter.

Instead of registering the degree of hardness of a water as the number of measures of standard soap solution consumed in producing the lather, he registered the degree of hardness as the number of grains of $CaCO_3$ or its equivalent of other soap-destroying salts in the gallon of water.

1918.—*What reagents and apparatus are required for the determination of hardness?*

1. *A standard solution of calcium sulphate* is obtained by grinding in a mortar 0·1965 gramme of crystallised silenite ($CaSO_4$, 2 H_2O) with a sufficiency of distilled water to dissolve it, and making up to the volume of a litre. Or 0·2985 gramme *barium nitrate* may be dissolved in distilled water and made up to a litre. Either of these solutions contains the equivalent, in calcium or barium salts, of 8 grains calcium carbonate per gallon.

2. A stoppered narrow-mouthed bottle holding 200 C.C., or as preferred by some, one holding 100 C.C.

3. *A burette* on stand divided into cubic centimetres and tenths of a cubic centimetre.

4. *The standard soap solution.*—A potash soap is best for the desired purpose, prepared thus: 15 parts of the lead plaster of the British Pharmacopœia (lead oleate) are warmed on a water-bath with 4 parts of potassium carbonate and rubbed in a mortar to a uniform consistence; then digested with ordinary rectified methylated spirits, allowed to deposit, and diluted with water in the proportion of three volumes of water to every five volumes of rectified spirit employed; in other words, the alcohol is reduced to

about proof strength, and only subsequent dilution is made with spirit of proof strength. The solution is then filtered.

Very commonly the soap solution is prepared by dissolving ordinary good undried Castile soap in the proportion of 14 grammes to the litre of a mixture of methylated rectified spirit and distilled water in equal volumes ; and there is no objection to this when no minute degree of accuracy is demanded. In any case it is well to prepare a stock bottle of strong soap solution, and to dilute some of the clear liquid from time to time with alcohol of proof strength and standardise it occasionally as soap solutions are apt to deposit in winter, or when long kept, and thus to lose strength.

1919.—*How is the soap solution standardised ?*

The soap solution is standardised by taking 50 C.C. of the standard calcium (or barium) solution, placing it in the bottle and running in the soap solution from a burette till a thick fine uniform white froth is produced on vigorously shaking the bottle, and should remain for five minutes when the bottle is placed on its side.

1920.—*What modification of the process is necessary if the water is excessively hard ?*

Should more than 9 C C. of soap be required, it is always well —and in the case of magnesium waters indispensable—to dilute the water under examination with its own bulk, or twice its own bulk, etc., of distilled water till not more than 9 C C. is required by 50 C.C. of the diluted water.

1921.—*Is the proportion between the soap used and the actual degree of hardness of a water constant ?*

It is not ; for according to the accurate observations of FAISZT and KNAUSZ, the degree of hardness corresponding to each C.C. of soap solution used increases constantly with the amount of soap used. [According to WANKLYN, distilled water requires 1 C.C. of soap of solution to produce a lather, and he deducts 1 C.C. from the number of cubic centimetres of soap solution, and the remainder gives the hardness in degrees. The later experiments of CLARK, confirmed by those of FAISZT and KNAUSZ, give 0·5 C.C. approximately, as the amount of soap required by 50 C C. of distilled water.

[It must not be forgotten that if the water be diluted the necessary correction for dilution must be made.]

1922.—*Describe a simple means of judging the degree of hardness of a water ?**

A rough means of judging of the relative degree of hardness of any sample of water, consists in placing a small quantity in a test glass, and adding to it a few drops of a standard solution of soap in alcohol, when a white turbidity will make its appearance depending in degree on the hardness of the water.

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* For other points in connection with the hardness of water *vide* Part I, Chapter I.

1923.—*By what processes may the hardness, and the salts or other bodies causing it, be determined?*

CLARK's very useful soap test offers a ready mode of determining this in a manner quite sufficient for hygienic and economic purposes. The processes with the soap test may be divided into two headings:—

I. The determination of the aggregate earthy salts, and free carbonic acid, as expressed by the term *total hardness* The aggregate determination can be divided into two kinds of hardness, viz., that which is unaffected and that which is affected by boiling, and these are termed the *permanent* and the *removeable hardness.*

II. The determination of the amount of certain constituents, as the lime, magnesia, sulphuric acid, and free carbonic acid. These results are only approximative especially in the case of the magnesia; but they are very useful, as they give us enough information for hygienic purposes, and are done in a very short time.*

1924.—*What are the two ways in which the hardness of water may be ascertained from the soap solution?*

1. Either by making the soap solution of a definite strength by careful standardising, so that each measure (grain or cubic centimetre) is equal to a grain of soap-destroying salts per gallon.

2. Or by making a water of a definite known hardness, by means of pure distilled water and chloride of calcium, and then seeing how much soap solution is required to neutralise the hardness of a definite amount of the artificial water; then test the hardness of the natural water, and compare the results.

1925.—*In general terms how is the "total hardness" estimated?*

A certain amount of the water under examination is introduced into a wide-mouthed bottle, just as it is, and well agitated to get rid of the carbonic acid, it being sucked out after each agitation. The soap solution is then added from the burette, with brisk agitation after each addition, until a lather is formed which remains for at least five minutes over the "whole surface," in an unbroken layer. The bottle is laid on its side. Let it lie for half-an-hour and agitate again, and add a few more drops of soap solution, if necessary; see that there is no break in the lather, even after half-an-hour's rest. Then read off the amount of soap solution used up, and this equals the degrees of hardness; only deduct a little, as a certain amount of soap is required to give a lather even in the purest water. This will then be the "total hardness"

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* PARKES' *Practical Hygiene*, 7th Ed.

1926.—*How may we prepare the standard solutions required in the estimation of hardness by* CLARK'S *method?*

Make a standard solution of barium nitrate by dissolving 0·26 grammes of pure barium nitrate in one litre of water. Next dissolve a piece of soft potash soap of British Pharmacopæia in equal parts of alcohol and water, filter and measure amount, say 210 cubic centimetres. Now take 50 cubic centimetres of the standard solution of barium nitrate and put into a clean glass-stoppered bottle and drop in the soap solution from burette, shaking occasionally and adding soap solution until a permanent lather is produced, which lasts for five minutes. If exactly 2·2 cubic centimetres have been used, the soap solution is of proper strength, if not, and suppose only 1·6 C·Cs. soap solution were used according to following rule of proportion:—

1·6 : 2·2 :: 210 : x, x = 288·7.* We must therefore dilute the original 210 C. Cs. with equal parts of spirit and water to 288·7 C.Cs. and again test for accuracy.

1927.—*How else may the standard soap solution be prepared?*

(*a*) By dissolving a piece of soft (potash) soap (of the British Pharmacopœia) or Castile* soap in a mixture of equal parts of alcohol and water.

[It may likewise be made by rubbing up 150 parts of the Emplastrum Plumbi (P B) with 4 per cent. of dry potassium carbonate (by which means carbonate of lead, and oleate of potassium are produced) this being then dissolved in rectified spirit and filtered.]

1928.—*What is meant by "degrees" of hardness?*

By *degrees* of hardness we signify that a definite quantity of water decomposes a certain number of cubic centimetres of a standardised soap solution. Thus 10 degrees of hardness means that 10 C C. of the standard soap solution have been used; that is, each C.C solution = 1 degree of hardness (FRANKLAND'S scale). Each degree of hardness causes the destruction of 2½ oz. of soap in 100 gallons of water used for washing clothes.

[According to WANKLYN'S method of estimating the hardness each C.C is equal to one degree of hardness; but according to the late Prof. PARKES' method each C.C. of his standard soap solution is equal to 10 degrees of hardness, each C.C. consisting of ten "measures," one measure indicating one degree of hardness.

1929.—*In general terms how do you estimate the "permanent" and "temporary" hardness?*

A known bulk of the water is boiled in a flask with a narrow neck for an hour, care being taken to keep up the water to its original bulk by the addition of distilled water; after the water has thus been deprived of its carbonic acid, the hardness is again estimated in the way just described; this result is then read as the "permanent hardness." The difference between this result and the one obtained by working with the natural water (total hardness) gives the "temporary hardness"—that got rid of by boiling.

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* Some analytical chemists speak highly of Castile soap for this purpose.

1930.—*Explain the initial cause of hardness in most waters?*

As soon as rain water reaches the earth, it dissolves out salts of different kinds, and frequently organic matters. Different soils contain different salts, and in accordance with the nature of the soil will be the quality of the water. If we boiled down a pint of *distilled water* we would find that in time it would all disappear—there would be nothing left. Doing the same with any spring or ordinary water in a clean white vessel, we would find a solid residue left. Why is this? It is because the rain water in falling to the ground, and passing over and through the soil, always finds saline bodies that it can dissolve and take away with it. The sea is, in this way, constantly having these salts added to it, and the earth is having them removed. A large part of the solid residue just mentioned consists of salts of lime and magnesia and is the initial cause of hardness in most waters.

1931.—*How is the hardness measured?*

By a standard soap-solution, 1 C.C. of which exactly precipitates 1 mgr of calcic carbonate. It is found that 1 C.C. suffices to give a lather when shaken with 70 C.C. of distilled water, and anything beyond this is due to the hardness, which is always stated in terms of calcic carbonate.

1932.—*How is the amount of the soap solution used read off?*

Thus:—If so many measures of the soap solution are required to neutralise the hardness of a definite amount of the artificial water containing a known amount of lime salts, what is the hardness of the natural water that uses up, say four times the amount of soap solution.

1933.—*What is the rationale of* CLARK'S *process?*

To add lime to hard waters, especially chalk waters, till the excess of CO_2 is neutralised; when this has taken place, both the lime added and that in solution are precipitated as carbonate, a minute quantity remaining in solution as carbonate of lime is not absolutely in solution in water. By this process not only is the water softened, but a very large proportion of the organic matter is precipitated.

1934.—*What are the solutions required for the hardness of water, and how are they prepared?*

(*a*) *Soap Solution.*

Dissolve some soft soap (pharmacopœial) in diluted spirit, and graduate by means of the following barytic solution.

Nitrate of barium	0·26 gramme.
Distilled water	1 litre.

2·2 C.C. (or 22 *measures*) of standard soap solution produce a permanent lather with 50 C.C. of the above solution.

1 measure (=$\frac{1}{10}$ C.C.) of soap solution=0·000 25 gm.=0·25 mgm. of calcium carbonate.

Correction for lather=2 measures of soap.

Short factors (when 50 C.C. of water are taken for experiment):—

For degrees of CLARK'S scale (1 : 70,000)=0·35.
" " Metrical " (1 : 100,000)=0 50.

(*b*) A weaker solution, each measure ($\frac{1}{10}$ C.C) of which is equal to 0·07 mgm. of $CaCO_3$ is sometimes used. The correction for lather would be 7 measures of soap. The corrected number of measures, divided by 10, gives the hardness in CLARK'S scale directly or multiplied by 0·14, the degrees on metrical scale *

1935.—*State briefly what is meant by* CLARK'S *process?*

It consists in the addition of a definite quantity of lime water, regulated by the hardness of the water to be softened , and is founded on the fact that carbonate of lime, *i e.*, chalk, is almost insoluble in water free from carbonic acid, though soluble in those containing carbonic acid in solution. When, then, a solution of burnt lime is added to such a water in the exact proportion indicated by its hardness, the lime combines with the excess of acid to form a carbonate, which falls together with the original carbonate, the solvent power of the free carbonic acid being withdrawn (WILLOUGHBY).

1936.—*How should the formation of the lather be watched?*

To watch the formation of the lather, the bottle should be laid upon its side, and the lather, to be satisfactory, must be capable of persisting for five minutes.

1937.—*What precautions should be taken with regard to the escape of the steam, and why is this precaution necessary?*

On no account must the steam from the flask be condensed and allowed to flow back into the boiling liquid, because the condensed water dissolves the escaping carbonic anhydride, which is thus continually returned to the contents of the flask in sufficient quantity to prevent the complete precipitation of carbonate of lime. Many serious errors have arisen from the neglect of this precaution.

1938.—*What is the reaction which takes place in* CLARK'S *process for softening waters?*

$$CaCO_3 + CO_2 + Ca(OH)_2 = 2\ CaCO_3 + H_2O.$$

The calcium carbonate, as it is precipitated, carries down organic and other matters, thus clearing and purifying the water. The quantity of lime required has been ascertained by Dr. CLARK.

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* PARKES' *Practical Hygiene*, 7th Ed.

He found that by adding one ounce of quicklime to a hundred gallons of water, for every degree of hardness, the water becomes soft and clean in twelve hours.

The carbonates at times are fixed salts (as in trough water). But when we speak of fixed hardness, we usually mean sulphate of lime and magnesia. The white deposits frequently seen on the interior of kettles and engine boilers consist of precipitated carbonate of lime and magnesia. The only acid usually present is carbonic acid in the gaseous state. This helps to keep the carbonates of lime and magnesia dissolved in the water. By boiling, the carbonic acid gas is driven off, and the lime and magnesian carbonates are precipitated. The same precipitation takes place if ordinary oxide of calcium is added to this water. It is useful to know to what agent the hardness is due, for such knowledge points to whether the water can be rendered fit for domestic purposes or not. Water from natural sources contains a varying amount of lime, magnesia and other salts. In accordance with the quantity of these salts is the hardness or softeness of water. Hardness is then generally due to excess of carbonate of lime and magnesia held in solution by excess of carbonic acid gas.

1939.—*How much of the standard soap solution is required to form a lather with distilled water?*

Distilled water requires approximately as much soap to yield a lather as 0·7 grain per gallon $CaCo_3$, or 1 part $CaCO_3$ in 100,000 parts of water. This is the excess of soap beyond that required to precipitate the calcareous salts of the water needed to produce a lather on agitation of the water with the soap.

1940.—*Give an example showing the method of making the calculation for the total and temporary hardness?*

Before boiling, 32 measures, and after boiling, 13 measures, of the soap solution were used.

13 — 2 (=11) ÷ 2 = 5·5 degrees of the Metrical scale.
5·5 × 0·7 = 3·85 degrees of CLARK's scale permanent hardness.

The difference between the total and the permanent hardness is the temporary or removable hardness, which in the example would be 15 — 5·5 = 9·5 degrees of the Metrical scale, and 10·5—3·85 =6·65 degrees of CLARK's scale.

The amount of permanent hardness is very important, as it chiefly represents the most objectionable earthy salts, viz., calcium sulphate and chloride, and the magnesian salts. The greater the permanent hardness, the more objectionable is the water. The permanent hardness of a good water should not, if possible, be greater than about 5° of the Metrical scale, equal to 3° or 4° of CLARK's scale.

The determination, then, of

1. The *total* hardness,
2. The *permanent* or *fixed* hardness,
3. The *temporary* or *removable* hardness,

will enable us to speak positively as to the hygienic characters of a water, so far as earthy salts are concerned.

1941.—*What is the method adopted in estimating the total hardness in water?*

Fifty C C of the water are placed into a shaking bottle. The standard soap solution is carefully dropped into the bottle from a graduated burette The bottle is now thoroughly shaken and allowed to stand, if there are any salts that give hardness to water they form insoluble oleate compounds and not a lather. We must then go on adding soap solution until we get a uniform lather of a beady character covering the surface completely and lasting for at least five minutes We now read off the number of measures (each measure = $\frac{1}{10}$ C.C. of standard soap solution) taken We deduct two measures from this, because it takes two measures to form a lather with distilled water, and then every two measures are equivalent to one degree of hardness according to the Metrical system.

1942.—*Explain this..*

Suppose we use 24 measures, that is, 2·4 C C. of the soap solution, the result will be 24-2 (correction for lather in distilled water = 22 ÷ 2 = 11° hardness (metrical) or 11 × ·7 = 7·7 degrees CLARK's scale.

[This does not mean that $CaCO_3$ is the entire cause of the hardness, or that it is the only salt present · it represents the quantity of soap solution used for a hardness that would be due to 7·7 gms. of $CaCO_3$ to the gallon.]

1943.—*How do we get the factor 2 to divide the measures by?*

Thus in the above instance 24 − 2 = 22 net measures used;
22 × 20 (there being 20 times 50 cubic centimetres in a litre);
= 440 × ·25 (the quantity of $CaCO_3$ represented by 1 measure of soap solution);
= 110 ÷ 10 (to reduce parts per million or litre to parts per 100,000) = 11° mettrical or 11 × ·7 = 7·7 grains per gallon. [Muliplying by 20 and by ·25 and dividing result by 10 is the same as dividing by the factor 2 at once]

1944.—*How much of the temporary hardness of water is removed by* CLARK's *process?*

Ten-elevenths of the temporary hardness can thus be removed, but the permanent is not affected, so that the hardness of waters of 15° to 20° cannot, as a rule, be brought down below 2½° to 3°. It seems at the same time to remove many organic impurities. The hardest waters are those of springs rising in the chalk limestone and dolomite, the last containing much magnesia, and being permanently hard. Thus, the Sunderland (dolomitic) water shows 30°, the Chatham 24°, Croydon and Kent Company 20° to 21° (WILLOUGHBY).

1945.—*What is the equivalent expressed in carbonate of lime of each "measure" of the standard soap solution?*

Each 0·1 C.C., or in other words, each *measure*, of our soap solution corresponds to ·25 mgm. of calcium carbonate. Multiply this co-efficient by the number of measures of soap solution used, and the result is the hardness of 50 C.C. of water expressed as calcium carbonate. Then, as we have acted on one-twentieth of a litre, multiply by 20 to give the amount per litre, and then by 0·07 to bring the amount to grains per gallon.

1946.—*How is the test carried out?*

Take 50 C.C. of water to be examined and place in a shaking bottle and drop in a measured quantity of soap solution, shake well and let it stand, if there be any salts it forms insoluble oleate compounds and not a lather. We must go on adding soap solution until we get a uniform lather of a beady character covering the surface completely lasting for at least 5 minutes. Lather should be permanent. We now read off the number of C.C. taken from the burette.

1 measure = $\frac{1}{10}$ of C.C Say we use 24 of this solution it equals 12 degress of hardness according to the Metrical scale or in grains per gallon ; 12 × 7 = 8·4 (according to CLARK's scale). Take 50 C.C. distilled water, use soap solution and wait The distilled water requires

2 measures to form lather ∴ 24—2 = 22.

From the 24 measures of soap solution taken subtract 2 for correction for lather in distilled water, which leaves 22, the total net measures of soap solution or 11° of hardnesss (Metrical) ; or 11 × ·7 =7·7 grains per gallon according to CLARK's scale.

[This does not mean that $CaCO_3$ is the entire cause of the hardness or that it is the only salt present it represents the quantity of soap solution used for a hardness that would be due to $CaCO_3$.]

1947.—*Give another example of the working of this calculation.*

Suppose 50 C.C. of water required 9 C. millimeters or 9 measures to form a lather ; ∴ soap solution 9—2 (for lather of distilled water = 7), [7 are net measures]. 7 × 20 (there being twenty times fifty cubic centimeters in a litre) = 140 × ·25 (the quantity of $CaCO_3$ represented by one measure of soap solution) 7 × 20 × ·25 = 35·00 per *million* parts ÷ 10 to reduce it two parts per 100,000 = $\frac{35}{10}$ = 3·5 grains per 100,000 = 35 × 10 ÷ 7 = 5 grains per gallon.

We divide the net measures by 2, because it comes to the same thing as multiplying by 20, and ·25 and ÷ 10.

1948.—*How is the determination of the total hardness of the water carried out ?*

Take 50 C.C. of the water; put it in a small stoppered bottle, and add the soap solution from the burette, shaking it strongly after each addition until a thin uniform beady lather spreads over the whole surface without any break. If the lather is permanent for five minutes, the process is complete, if it breaks before that time, add a drop or two more of the solution, and so proceed until a lather be obtained that is permanent for five minutes.

Then read off the number of *measures* of soap solution used.

The amount of this total hardness is, for convenience, usually expressed in England in the manner proposed by Dr. CLARK, *i.e.*, though dependent on various causes, it is expressed as equivalent to so much calcium carbonate per gallon, and in CLARK'S scale 1 grain of calcium carbonate per gallon is called 1 degree of hardness.

1949.—*What are the chief constituents of the "volatile solids" ?*

Organic matter, nitrites, ammonia, and chlorides.

1950—*What is the purpose served by the estimation of the solids ?*

It serves as a check to the determination of the total solids.

1951.—*In testing very hard waters what preparations are to be adopted ?*

In trials of waters above 16° hardness, 100 measures of distilled water should be added, and 60 measures of the soap test dropped into the mixture, provided lather is not found previously. If at 60 test measures of soap test; or at any number of such measures between 32° and 60°, the proper lather be produced, then a final trial may be made.

1952—*How is the test then conducted ?*

100 test measures of water under trial are mixed with 100 measures of distilled water, well agitated, to this mixture soap test is added until the lather is produced. The number of test measures required is divided by 2, and the double of such degree will be the hardness of the water

1953.—*Give an example.*

Suppose half the soap test that has been required correspond to $10\frac{5}{10}$ degrees of hardness, then the hardness of the water under trial will be 21. Suppose, however, that 60 measures of the soap test have failed to produce a lather, then another 100 measures of distilled water are added, and the preliminary trial made until 90 test measures of soap solution have been added Should a lather now be produced, a final trial is made, by adding to 100 test measures of the water to be tried 200 test measures of distilled water, and the quantity of soap test required is divided by 3; and the degree of hardness corresponding with the third part being ascertained by comparison with the standard solution, the degree multiplied by 3 will be the hardness of the water. Thus, suppose 85·5 measures of soap solution were required $\frac{85\cdot5}{3}=28\cdot5$, and on referring to the table, this number is found to correspond to 14°, which multiplied by 3, gives 42° for the actual hardness of the water.

1954.—*To ascertain exactly the hardness of water what should be done before applying the soap test ?*

Previous to applying the soap test it is necessary to expel from the water the excess of carbonic acid, that is, the excess over and above what is necessary to form alkaline or earthy bicarbonates, this excess having the property of slowly decomposing a lather once formed. For this purpose, before measuring out the water for trial, it should be shaken briskly in a stoppered glass-bottle half filled with it, sucking out the air from the bottle at intervals by means of a glass tube, so as to change the atmosphere in the bottle; 100 measures of the water are then introduced into the stoppered phial, and treated with the soap test, the carbonic acid eliminated being sucked out from time to time from the upper part of the bottle. The hardness of the water is then inferred directly from the number of measures of soap solution employed.

1955.—*What are soft and hard soaps respectively ?*

Soft soaps are principally oleates of potash, but contain also some stearate of potash.

Hard soaps are principally stearates of soda, but they contain, besides, a little oleate of soda, also palmitate and resinate of soda, where palm oil and resin are used in their manufacture.

1856.—*What was* Dr. CLARK'S *standard for hard water ?*

Sixteen degrees.

1957.—*What does this mean ?*

Water which contains 16 grains of pure calcium carbonate per gallon.

1958.—*State briefly how the permanent hardness is determined.*

Boil a measured quantity of the water briskly in a wide-mouthed flask for half an hour, adding distilled water to make up for that evaporated. Allow the water to cool after closing the mouth of the flask. Make up with distilled water to the original bulk taken. Decant if possible, if not, filter, the quantity required for examination. Proceed as in the estimation for the temporary hardness.

1959.—*State briefly how the temporary hardness is determined ?*

Put 50 decems of the water in a well stoppered square 8-ounce bottle. From the burette run in small quantities of the soap solution at a time. Shake the bottle vigorously for about a quarter of a minute. If a lather is produced, lay the bottle on its side and notice if it remains *five* minutes; at the end of that time turn the bottle round on its opposite side and note if the lather breaks. If it does, add more of the soap solution and repeat the process. When a permanent lather is produced note the number of measures of soap solution used. Now repeat the process on a fresh sample of water, running in the soap solution to within a few measures of the former quantity used. From this point run in the soap by drops so as to obtain the exact quantity used and as a check upon the former estimation.

1960.—*Describe* CLARK'S *process for softening water on a small scale. On what principle does it depend?*

The method is applicable to chalky waters, that is, water containing extra proportions of carbonate of lime. By the addition of lime water the chalk is precipitated and the water left above is clear, colourless, and soft, not holding in any sensible degree either a solution of quicklime or bicarbonate of lime. In houses it is easily carried out, by having a quantity of ordinary lime in a well stoppered bottle, using it to soften the water as required. The proportion of lime to the water is one in thirteen. Two jugs may be used, one holding thirteen times as much as the other. For each jugful of the largest kind of hard water mix the contents of one of the small jugs of lime water. The chalk after a little while deposits at the bottom when the softened water can be poured off.

1961.—*Describe* CLARK'S *process for removing the hardness of water on a large scale.*

The water collected in large tanks is treated with a sufficiency of lime water to neutralise the free carbonic acid present. As the carbonate of lime present in the original water is only retained in solution by the excess of carbonic acid, it follows that if this be removed, the carbonate of lime will be precipitated. The lime water acts, therefore, by neutralising the carbonic acid, forming with it insoluble carbonate of lime, which is thus precipitated together with the carbonate of lime previously dissolved in the water. By this means, not only is the lime almost entirely removed, but a certain degree of organic purification takes place by the precipitated lime carrying down with it a considerable amount of the organic matter present.

1962.—*What regulates the quantity of lime required to remove the hardness?*

The quantity to be added to the water is made known by ascertaining the amount of total hardness.

1963.—*How much lime is used in the process?*

One ounce of quicklime should be added to 100 gallons of water for every degree of hardness.

1964.—*How is the lime treated before being added?*

It is first to be slaked and stirred in a few gallons, and immediately poured into the whole quantity, taking care to repeat the operation, and to thoroughly mix the whole contents together.

1965.—*What is next done?*

After this it should be left at rest, and it will become sufficiently clear in three hours for external use, but should not be drunk for twelve hours.

1966.—*What are the chief objections to* CLARK'S *process?*

1. It requires large extra reservoirs when done on the large scale, as large volumes of water have to be left at rest for many hours; this, of course, entails expense.
2. The great quantity of chalk that accumulates at the bottom of the reservoirs, and that must be carted away occasionally, also entailing extra expense.
3. The softened water is more likely to attack lead pipes.

1967.—*How is* CLARK'S *process carried out for softening Thames water?*

The working of the process (CLARK'S) may be described shortly as follows:—For Thames water, the proportion of lime to be used should be about $14\frac{1}{3}$ cwt to each million gallons. The lime in the form of quicklime is first slaked with water in a tank, into which the water to be softened is gradually allowed to flow, thorough mixing must be ensured by wooden paddles or other mechanical means. The water becomes milky in appearance from precipitation of the chalk, and must then be allowed to settle, for 12 hours, and subsequently decanted. Besides chalk, a certain amount of colouring and organic matters are removed from the water by this process. It is important that uncombined lime should not pass out with the purified water, as would be the case if lime were added in excess of that required to combine with all the carbonic acid holding the chalk in solution. To detect uncombined lime, it is only necessary to add a few drops of a solution of nitrate of silver to the treated water in a shallow white dish, when a yellow or brownish colour is produced if uncombined lime is present, but only a white precipitate of chloride of silver if there is none present.

1968.—*What are the waters to which* CLARK'S *process are specially applicable?*

Those containing excess of $CaCO_3$ held in solution by excess of CO_2.

1969.—*What quantity of lime is added to remove the hardness?*

The quantity to be added to the water is made known by ascertaining the amount of total hardness; the actual amount usually employed is one ounce of quicklime to every 100 gallons for every degree of hardness.

1970.—*Give some useful data regarding hardness.*

1 degree (1°) CLARK's scale = 1·4 degree (1°·4) on the centesimal scale (parts per 100,000).

1 degree (1°) CLARK's scale=0·8 degree (0°·8) on the German scale.

1 grain $CaCO_3$=1·11 gr. $CaCl_2$ = 1·38 gr. $CaSO_4$ = 0·56 gr. CaO = 0·84 gr. $MgCO_3$ = 0·4 gr. MgO in soap = destroying power.

1 grain per gallon $CaCO_3$ = 1·43 Mg per litre.

1971.—*What is the rationale of the process of the soap test?*

When an alkaline oleate is mixed with pure water, a lather is given almost immediately; but, if lime, magnesia, iron, baryta, alumina, or other substances of this kind be present, oleates of these bases are formed, and no lather is given until the earthy bases are thrown down. Free (but not combined) carbonic acid prevents the lather. The soap combines in equivalent proportions with these bases, so that if the soap solution be graduated by a solution of known strength of any kind, it will be of equivalent strength for corresponding solutions of other bases. There are, however, one or two points which render the method less certain. One of these is, that, in the case of magnesia, there is a tendency to form double salts (PLAYFAIR and CAMPBELL), so that the determination of magnesia is never so accurate as in the cases of lime or baryta. Carbonic acid appears to unite in equivalent proportions when it is passed through the soap solution; but if it be diffused in water, and then shaken up with soap solution, two equivalents of the acid unite with one of soap.*

1972.—*What precaution is necessary if magnesian salts are present?*

If magnesian salts are present a *scum* is formed, therefore add the soap solution very slowly and shake more briskly after each addition. If the water is above 16° hardness mix 50 decems of the water with an equal volume of recently boiled distilled water cooled in a stoppered vessel and determine hardness as before. The result must of course be multiplied by 2.

1973.—*What is the strength of* WANKLYN's *standard soap solution?*

It contains exactly sufficient soap in 1 C.C. to precipitate one mgm. of $CaCO_3$. When therefore the 70 C.C. are taken and a certain number of C.C. of standard soap solution, it is as if an actual gallon of water had been taken, and tested with a certain number of measures of standard soap solution whereof each measure contained soap equivalent to one gramme of carbonate of lime.

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* PARKES' *Practical Hygiene*, 7th Ed.

4.—*Why is 70 C.C. taken?*

Because it forms a sort of "miniature gallon"; they contain as many mgms. of water as there are grains in a gallon.

1975.—*What is the* PORTER-CLARK *process?*

It is a modification of CLARK'S. Instead of waiting for slow subsidence, which takes ten or twelve hours, the precipitated calcic carbonate is removed rapidly by filtration through cloth, under pressure.

The PORTER-CLARK process is an admirable one for removing excess of temporary hardness, and the carbonate of calcium deposited in the process carries down with it organic matters, so that the filtered water is fairly soft, clear, and of a fine blue tint when viewed in thick layers.

1976.—*What is* ATKIN'S *patent system of softening water?*

In principle it is the same as CLARK'S process, the difference consisting in a provision made in the ATKIN system for filtering the water concurrently as it is softened, instead of precipitating the lime in tanks.

1977.—*Mention another method of reducing hardness.*

The addition of a solution of barium chloride ($BaCl_2$).

1978.—*Explain the rationale of this process.*

The addition of the $BaCl_2$ converts the sulphate of lime into a chloride; the $BaSO_4$ is precipitated. As the $CaSO_4$ is converted into a chloride, CO_2 is passed through the water which converts it into carbonate of lime and this is thrown down.

1979.—*What are the disadvantages of this process?*

1. It is expensive.
2. $BaCl_2$ is not altogether a non-poisonous agent.

1980.—*Give an example as to its practical application.*

Original hardness	32
50 C.C. barytic solution	22
	54
After precipitation	45
Difference	9

$\cdot 24 \times 9 \times 2 = 4\cdot 32$ parts per 100,000; $4\cdot 32 \times 0\cdot 7 = 3\cdot 02$ grains per gallon.

Usually this process gives good results. Occasionally, from some cause which is not clear, the barium sulphate does not precipitate. This does not depend on the amount of sulphuric acid. The ease with which this process is carried out renders it useful. The barytic solution is only strong enough to precipitate 6·72 grains of sulphuric acid (SO_4) per gallon, so that half the water only must be taken, or less, if the sulphuric acid be evidently in large amount.

1981.—*What is* MAIGNEN'S *patent process?*

This is founded on CLARK'S principle, but the apparatus is more adapted to domestic requirements. In its simplest form of application the softening material, called *anti-calcaire* (an admixture in powder of lime, soda and alum) is stirred up in the water to be treated and the precipitate allowed to settle. One pound of the powder costing sixpence, will sufficiently soften from 300 to 500 gallons of water.

[The resources of analytical chemistry are not as yet sufficiently developed to determine the existence and nature of all organic substances with which water may be contaminated, and the presence of some of the more subtle and dangerous of these is manifested only by their pathological effects.]

1982,—*How could you represent the disadvantages attaching to each degree of hardness in soap?*

By the fact that about 2½ ounces of soap are wasted in washing purposes in 100 gallons of water of one degree of hardness, each grain of carbonate of lime wasting about ten grains of soap.

1983.—*Does the hardness in different waters vary?*

Yes, within very wide limits. Thus in the deep wells in magnesian limestone it varies from 14°—57°; in the deep wells from chalk beds it averages 27°. In the water from Bala Lake, Wales, the temporary hardness is 0°·1, the permanent hardness 0°·3, in the Lock Katrine water there is no temporary hardness and 0°·9 permanent hardness; in the water from the Thames, above Reading, temporary hardness 12°·8, permanent 8°·2, total 21°, from the Thames, above Hampton, temporary hardness 17°·9, permanent 6°·6.

1984.—*What is the limit of hardness allowable?*

Fourteen degrees of hardness is the allowable limit in waters used for drinking and cooking purposes. Some authorities hold that water having anything beyond 8 or 9° of hardness ought not to be used without being softened; others consider that even as much as 40° is harmless if the hardness arises from chalk only.

If the hardness arises from $MgCO_3$ and $CaSO_4$, and exceeds 14°, it is not a suitable water for drinking purposes.

[Persons who for a long period have been accustomed to a hard water and are then obliged to use a soft one, are very liable to suffer from digestive derangements.]

1985.—*Which are the hardest waters?*

Those of springs rising in the dolomite and chalk limestone, the former, containing magnesia, being permanently hard.

1986.—*What is the effect of boiling upon water containing much* $CaCO_3$*?*

It drives off the CO_2, which holds the excess of $CaCO_3$ in solution; the latter falling to the bottom as a precipitate; the water which was "hard" is thus rendered "soft."

1987.—*What are the objections raised against* CLARK'S *process?*

The following objections have been raised against CLARK'S process for softening water:—

1. That the softened water attacks lead—denied by WANKLYN.
2. That the process is not applicable to waters containing organic matter in large quantity, because the chalk precipitated will not subside—answered by condemning all waters with a *large* quantity of *organic* matter.
3. That in carrying out the process on a large scale, great volumes of the water must be left at rest for many hours, extra reservoirs are required, and the expense of water-works thereby greatly increased.
4. That the quantity of chalk which would accumulate at the bottom of the reservoirs would require frequent removal and entail expense.

The two last objections can only be answered by comparing the relative cost of other proposed schemes.*

1988.—*In there any special process that requires a very hard water?*

Yes, that of *brewing*. In this case the water may contain as many as 28 degrees of permanent hardness to the gallon, especially if from calcium in the form of sulphate.

1989.—*Cite an example in which this is the case.*

Burton-on-Trent.

1990.—*Why is hardness advantageous in this process?*

The hard water keeps out the colouring matter of the salt.

1991.—*How may the hardness of chalk waters be adequately represented?*

By the fact that every 1,000,000 gallons contains about 1½ tons of chalk.

1992.—*How does boiling affect the degree of hardness of water?*

Some hard waters are softened by boiling; others are not. The hardness of water removed on boiling is due mainly to the presence of *carbonate of lime and magnesia;* whilst the water, the hardness of which is but slightly, if at all, affected, contains *sulphate of lime.* Chalk waters are most influenced by boiling, as the carbonate of lime is held in solution by the excess of carbonic acid present. When a chalk water is boiled, the carbonic acid is expelled, and the carbonate of lime is to a great extent precipitated.

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* WANKLYN'S *Water Analysis.*

The hardness, due to carbonate of lime, is termed "temporary," as it can be thus removed; that due to the sulphate of lime and magnesia is termed "permanent," as it is not removable by boiling. It is always desirable to know to which of the above the "hardness of water" is due, as, in excessive cases, a knowledge of the cause would determine whether the water might be rendered fit for domestic purposes.

The Chemical Commission of 1851 ('Quart. Jour. Chem. Soc.,' Vol. iv., p. 388, 1852) found that the water supplied by the New River Company to London, having a total hardness of 14° to 15° and a permanent hardness of about 2°, when drawn on six different occasions from the fixed boiler of a kitchen range, had a hardness of 5°·4, 4°·9, 4°·1, 4°·9, and 5°·3; the average being 4°·8, or one-third of the original amount.

1993.—*What effect has hardness on the infusing of tea?*

In tea-making, hard water is considered to yield a more delicate infusion than soft water, and is hence preferred. A soft water, on the other hand, yields with tea a darker and better infusion, and is hence more esteemed for the purpose by the lower orders, who desiderate 'strength' of tea. The chief difference in this respect between a hard and a soft water is that when a hard water is used a longer time is required for the infusion of the tea.

For most culinary purposes a hard water is objectionable, and the presence of calcium salts is said to harden the fibre of meat during boiling. Sulphate of calcium, too, when boiled with leguminous seeds, is asserted to form hard indigestible compounds with the legumin which they contain.

1994.—*Does experience show that the use of hard water is dangerous to health?*

It does not. Some of our town supplies, as, *e.g.*, those of Bristol and Sunderland, are very hard, the water supplied to Sunderland containing magnesia and sulphates, the equivalent of 14 grains anhydrous and 28 grains crystallised sulphate of magnesium per gallon; yet the Medical Officer of Health has not been able to trace any inconvenience to health, much less disease, to its use, and it is believed to be a good wholesome water, though having a hardness of 25°.

The waters of the valley of the river Trent, and very many of those derived from wells and springs in the new red sandstone formation, are intensely seleniferous, *i.e.*, abound in sulphate of calcium, and yet are not generally considered harmful.

All are agreed that where the hardness of water is due to the presence of carbonate of calcium, and to a lesser degree of carbonate of magnesium, *i.e.*, when the hardness is temporary or removable, little harm ensues; but that when the hardness is permanent, due to the presence of the sulphates, nitrates, and chlorides of calcium and magnesium, the dietetic value of a water is greatly impaired. How far this opinion is based upon a solid basis of facts is at least uncertain.

1995.—*What is the money-loss involved in the use of softening hard water?*

The money-loss involved in the use of hard water has been much exaggerated. The difference between the use of water of 2° and one of 14° of hardness is about 128 grains of yellow soap per gallon, or 1¾ oz. per 6 gallons, 6 gallons being the ordinary consumption of water per head per day for washing purposes; it being assumed that the water is used cold. The money-value of this amount of soap is 0·04*d.*; whilst the cost of softening 35 gallons of water—the daily supply per head in towns—by the PORTER-CLARK process is 0·012*d.* only. The difference is equal to rather more than 10¼*d.* per head per annum.

When soda is used in addition to soap, as in ordinary laundry work, the loss of soap is much less, since the soda (carbonate of sodium) precipitates the calcium salts in a form which prevents the destruction of soap.

The case against the use of hard water was ably put by the Chemical Commission of 1881, who stated that it is in the more careful washing for the upper and middle classes that the advantages of soft water become fully sensible; for when a hard water is heated the carbonate of calcium is precipitated on the linen, carrying down with it the colouring matter of the dirty water, and producing stains which there is the greatest difficulty in afterwards removing from the linen. The colouring matter from the water is thus indeed fixed upon the cloth by the precipitated calcium salt with the tenacity of a mordant.

If the hands be washed in water before this artificial softening is complete, the insoluble lime soap will be precipitated on the skin, producing a harsh, unpleasant sensation, and if linen be washed in such water, the insoluble soap precipitate is deposited within and between the fibres of the fabric.

1996.—*How do sulphate and carbonate of lime in water tively affect steam boilers?*

The sulphate of lime, although somewhat soluble in cold water, deposits because it is almost completely insoluble in water having a temperature of about 130°C. a temperature which is reached when the pressure of steam in the boiler is that of 2½° atmospheres. It forms a scale which is very coherent and difficult to detach, while the carbonate of lime, in the absence of other deposits, generally settles as a loose sludge, which, however, under some circumstances, becomes tolerably compact. [Lengthy remarks on boiler incrustation and the boiler corrosion does not come within the objects of this CATECHISM.]

1997.—*What are the disadvantages and risks of these deposits?*

1. As the bottom of the boiler (next the fire) becomes thickly coated, much more coal must be used to keep up the steam; hence this is wasteful and entails more expense.

2. The boiler plates are allowed to become red hot, as the water cannot reach the lower ones, and this leads to rapid corrosion and wearing away of the plates and weakening of the boiler.

3. The deposit or crust may crack, and allow the water suddenly and directly to reach the red hot plates, and this is followed by a very rapid generation of steam, and probably bursts the boiler.

1998.—*What material is chiefly used for water mains and how is it affected by the water?*

The material most commonly employed for the main distribution pipes is cast-iron. Cast-iron is readily acted upon and caused to rust by most waters, and the water, by exposure to the iron, acquires more or less of a rusty character. The presence of what little iron is actually dissolved is of no significance, and the suspended particles of iron rust can hardly be regarded as deleterious to health.

The water is, however, sometimes rendered unfit for washing, and becomes objectionable in appearance. The action on the pipes is so great, especially when soft waters are conveyed through them, that they are seldom used now except the surface be protected in some way from corrosion.

1999.—*How are cast-iron mains protected from corrosion?*

The process commonly employed is that devised by Dr. R. ANGUS SMITH: the newly cast pipes, which must be free from rust, are heated to a temperature of some 500° F. and then dipped, perpendicularly, into a hot bath of coal-tar pitch mixed with a small proportion of heavy coal oil. In this bath they are allowed to remain for a short time and then withdrawn. The firmly coherent coating thus formed does not afford absolute protection against rust, but it has proved very efficient in practice. Of course, from a sanitary point of view, this surface is as good a one as could be desired.

2000.—*Describe a more recently introduced method of preventing corrosion?*

It has been proposed by Professor BARFF, of London, to protect articles of iron, among other things water pipes, from corrosion, by covering them with an artificial coating of the black oxide of iron. The coating is produced by exposing the metal to superheated steam at a high temperature, and when once formed it protects the iron from atmospheric and other agencies which would corrode it. If the process proves practicable as far as expense goes, it will, no doubt, be of great use, especially in protecting iron service pipes.

2001.—*Name some places where* CLARK'S *process is carried out on a large scale.*

Caterham, Canterbury, Colne Valley Water Works, etc.

2002.—*What geological formations furnish hard waters?*

The following geological formations almost invariably yield hard waters: 1. Calcareous silurian; 2. Calcareous devonian; 3. Mountain limestone; 4. Calcareous rocks of the coal-measures; 5. New red sandstone; 6. Conglomerate sandstone; 7. Lias; 8. Oolites; 9. Upper greensand; 10. Chalk.

2003.—*What is there peculiar about the water from clays?*

The amount of permanent hardness in such waters is always great, as the London, Oxford, Kimmeridge and Lower Lias clays; or in places where there are large deposits of calcium sulphate, as at Montmartre, near Paris, (hence the name Plaster of Paris given to desiccated calcium sulphate).

2004.—*What is the average of hardness of the Thames water-supply to London?*

About 14 degrees.

2005.—*What diseases are connected with the consumption of waters containing excess of mineral matters?*

Hard waters produce dyspepsia, constipation, and sometimes diarrhœa; goitre and cretinism are associated with magnesian limestone formation, but not everywhere, for magnesian limestone occurs in Scotland, Ireland and Scandinavia, without the presence of these diseases; it has been suggested that when iron is in it, a different effect may be produced. Calculi and diseases of bones are alleged to be caused by drinking such water. *Iron* in quantity may produce headache and dyspepsia. Brackish water from wells near the sea may set up diarrhœa.*

2006.—*What are the disadvantages of the use of hard water?*

There are many disadvantages associated with the use of hard water:—

1. The waste of soap used in washing clothes.
2. The difficulty of cooking food, especially vegetables with it. Tea can be but imperfectly infused in it.
3. The fact that it is believed by some to cause certain diseases —goitre, cretinism, stone in the bladder, dyspepsia, etc.

ALLEN'S *Aids to Sanitary Science.*

those supplied by soft water. Yet an important fact must not be overlooked, and that is, that the water-bearing strata of four-fifths of the world consists of lime, or contain salts of lime which impart hardness to water ; therefore the vast majority of people living use hard water. Usually people become accustomed to the water of the place in which they live, and only recognise the difference on leaving it. The effects of this difference in hardness of water should be remembered in ordering patients away for a change on account of ill-health.

There is no doubt that medical opinion has undergone some change as to the alleged unwholesomeness of hard waters ; and it is now generally accepted that excessively hard waters are injurious to the digestive processes, though proof of this is difficult, and the conclusion has been doubted.

The use of a water of more than 20 degrees of hardness (CLARK's scale) is undesirable ; and an ordinary good water ought not to have more than 15 degrees of hardness. The use of a water of 25 degrees of hardness is, however, permissible when no softer water is available. The permanent hardness of a good water should not exceed 5 degrees.

2015.—*What may be said in favour of soft waters?*

There is no doubt that the evidence is conclusive and cogent as to the great advantage of soft water over hard for washing, and, with some few exceptions, for general manufacturing purposes ; and if we were treating of the supply of a town like those in the manufacturing districts of England, where large quantities are required for these purposes, the objection to the present supply (to London) would assume a more serious aspect. But the amount of manufacturing industry in the metropolis, of a kind to demand a large supply of soft water is exceedingly small in proportion to the population, and it must be recollected that the softening influence of boiling largely diminishes the evil. To these exceptional cases also, the softening process of Dr. CLARK would be easily applicable.

There is no doubt, also, that in personal ablutions and washing generally the use of soft water is more pleasant and economical, but we think the latter advantage has been much over-estimated. The soap is usually applied out of the water, and therefore it is with the small quantity of water adherent to the object washed that we have to deal, and not with the total quantity used for rinsing to remove the soap. It is certain, however, that when a soft water or rain water can be obtained for these purposes, it will always be preferred. 'On the whole we cannot see that the advantages of soft water are of sufficient importance to justify going to a great distance to obtain it, in place of the ample supply near at hand.'

The Rivers Pollution Commissioners stated that the saving of soap the use of soft water is most obvious in the washing of the person ; and for baths soft water is undoubtedly most agreeable and beneficial. Its superior efficiency to hard water in washing floors and walls is calculated also to promote greater cleanliness in the dwellings of all classes, both within doors, and externally; whilst in the occasional domestic washing of linen, the smaller preparation necessary for washing in soft as compared with hard water, the saving of soap waters in a high degree desirable. The saving of labour is also considerable, and tends to promote cleanliness.*

2016.—*Name the softest waters ?*

Rain water is the softest, but as a rule, lakes yield waters of a very low degree of hardness; thus, Bala Lake gives only 0·28, Glasgow water (Loch Katrine) 0·0, and Manchester (Thirlmere) 2° to 3°.

2017—*What two diseases have been specially connected with the use of hard water ?*

Goitre and cretinism have been attributed to the habitual drinking of excessively hard water.

M. SAINT LAGER, basing his opinion partly on certain negative instances, partly on his own experiments with the soap test, which show no relation between hardness of water and goitre, and partly on the negative results of experiments on animals with calcium sulphate and magnesian salts, denies altogether the connection between goitre and calcium and magnesium sulphates and carbonates. He states also that M. GRANGE has now himself given up the belief of magnesia being the essential agent of goitre, and argues that the constituent of the water which is the actual cause is either iron pyrites (ferrum sulphide), or more infrequently copper or some other metallic sulphide. And he explains MCCLELLAN's results by the supposition, based on an expression of that writer, that in the limestone districts of Kumaon the water had traversed the metalliferous strata of the rocks. SAINT LAGER does not support his opinion by actual chemical analyses, but he brings forward geological evidences on a large scale to prove that the endemic appearance of goitre coincides with the metalliferous districts. He has also made experiments on animals with iron salts which do not appear conclusive, although he believes he produced in some cases an effect on the thyroid. His hypothesis seems to fail from his want of chemical analyses. He has made out a case for inquiry rather than for conclusion.

In some observations made by Dr. FERGUSON on the goitrous part of the Baree Doab district (a boulder-gravel subsoil), the water is said to be largely charged with lime. In the jail at Durham, JOHNSTON states "that when the water contained 110 parts per 100,000 (chiefly of lime and magnesium salts) all the prisoners had swellings of the neck; these disappeared when a purer water, containing 26 parts per 100,000, was obtained."

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* Sixth Report of the Rivers Pollution Commissioners.

Goitre may be rapidly produced. **Bally** noticed that certain waters in Switzerland would cause it even in eight or ten days, and cases almost as rapid have occurred in other places.*

Dr. J. B. Wilson (late A.M.D.) carried out some inquiries at Bhagsoo, Dhurmsala, where goitre prevails extensively. He analysed specimens of the drinking water within a radius of ten miles, and found them exceptionally pure, only three showing traces of lime, and none giving any evidence of magnesia or iron.

It seems, therefore, that the question is still undecided, and it is much to be desired that more extended inquiry should be made, with careful analyses, such as have been made by Dr. Wilson—as well as records of local and other conditions, which probably contribute more or less to the production of the disease.

2018.—*Has* Clark's *process any other property besides that of reducing the hardness ?*

Yes; it removes many organic impurities.

2019.—*Give an idea of the relative amounts of each of the agents required in the softening of water and the expense entailed.*

	£		
1 cwt. of quicklime costs	0	0	8
4¾ cwts. of carbonate of soda cost	2	17	9
20¼ cwts. of soap cost	47	1	8

So that 1 cwt. of lime will do as much as a ton of soap, and of course, at a very much less cost.

2020.—*What measures have been proposed to overcome the hardness of water ?*

Various remedial measures have been tried, but, with few exceptions, not in a sufficiently thorough way. To neutralise the acidity of the water it has been exposed to fragments of limestone, and the conduits have been lined with the same material, but the limestone soon becomes inert, probably by incrustation and frequent removal of the surface is necessary. Measured quantities of lime have also been added to the water, and powdered chalk has been proposed for use in like manner. In pursuance of a recent hypothesis, the water has been charged with traces of silica by filtration through powdered granite or flint. More evidence is needed before any final conclusion can be arrived at, and it is at least possible that the mischief may not always be due to the same cause.

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* An outbreak of acute bronchocele is recorded by M. Colin as having occurred at Briançon in the Hartes Alpes, France.

A case of the same disease is also recorded by the Author in the *Indian Medical Gazette* for 1881. It was that of a healthy male adult, who having previously had a small goitre, suffered from symptoms of urgent dyspnœa, after carrying a heavy load 13 miles up-hill, the thyroid gland having increased enormously in size in two days' time.

CHAPTER XXIV.

EXAMINATION OF WATER—*continued.*

ORGANIC MATTER IN WATER.

2021.—*What forms of organic matter are found in water?*

Animal and vegetable matter, together with the products of their decomposition. The nature of these matters is not definitely known as many of the compounds are highly complex.

2022.—*Is it important to know the nature of the organic matter present in water?*

It is very important to know whether the organic matter is of animal or vegetable origin, and whether the quantity is considerable.

2023.—*How is this information obtained according to* FRANKLAND?

The only item in water analysis which furnishes direct evidence on this head is the "total inorganic nitrogen" according to FRANKLAND'S view.

2024—*What may be the nature of the organic suspended impurities present in water?*

Particles of dead animal and vegetable life, vegetable organisms—bacilli, bacteria, vibrios, micrococci—some harmless, some putrefactive and others pathogenic—animal forms—germs, spores, ova, animalculæ, and various forms of protozoa; confervoid growths, algæ, etc.

2025.—*Of what may the inorganic matters consist?*

Finely-divided silica scales, chalk, peroxide of iron, clay, chalky marl, magnesium sulphate and other mineral substances.

2026.—*Which is the most important impurity in water?*

The organic.

The *organic* impurities are by far the most important constituents of water, and they are the most powerful in producing disease. The *saline* bodies, when in excess, are not without their injurious effects, but when found they are more or less constant and unvarying, can be determined with accuracy, and the diseases they bring about can be readily and with certainty connected with them. Dead organic matter may give rise to diarrhœa, dysentery, etc., but living organic matter in the form of specific micro-organisms may bring about specific diseases, such as cholera and enteric fever.

2027.—*Are we able to define its exact nature?*

We are not able by chemical means to determine the origin of the organic matter.

2028.—*What bodies are included in the term "organic matters"*

For hygienic analytical purposes they are divided into:—Nitrogenous organic matters and oxidisable organic matters, chiefly non-nitrogenous.

2029.—*Which is the more injurious in water, animal or vegetable organic matter?*

Animal matter.

2030.—*How are they distinguished?*

By their effects; vegetable matter even in large quantities is comparatively harmless; animal matter contains a large amount of total solids, chlorine and ammonia; they may also be distinguished by the microscope and other methods adopted in water analysis.

2031.—*What forms of organic matter may be found in water?*

Vegetable—nitrogenous and non-nitrogenous.

Animal—all animal matter is to some extent nitrogenous.

2032.—*What is the difference in the products of decomposition of non-nitrogenous and nitrogenous organic matter?*

When organic substances containing no nitrogen are oxidised, they are converted into carbonic acid and water—substances which in aerated water can, of course, no longer be identified. Nitrogenous organic bodies, however, such as sewage and animal matter generally, yield, in addition, nitrous and nitric acids, and ammonia; these reacting on mineral substances in the water, form nitrates, nitrites, and ammonium salts, which remain dissolved in the water and can be accurately determined.

2033.—*What ready means may we use for estimating the amount of organic matter by means of permanganate of potash?*

By finding out what quantity of a standard solution of it is discolorised by a litre of water in a certain time. This gives a rough estimate of the extent of contamination to which water has been subjected by decomposing organic material. As in the case of the chloride of gold test, animal matter discolorises more rapidly than vegetable.

2034.—*What is the dephenylamine test for oxidised nitrogen?*

A 2 per cent. solution of dephenylamine in strong sulphuric acid is spread out in a thin layer upon a white porcelain plate. A drop of the sample water is allowed to fall in the centre, and any trace of oxidised nitrogen is revealed in a few seconds by a blue tint throughout, or, at the line of contact.

2035.—*Give another simple volumetric test for oxidised nitrogen.*

Half a litre of sample water is evaporated down to 2 C.C. and then transferred to a tube inverted over mercury. About 3 C.C. of pure sulphuric acid are passed into the tube, and after shaking, all the oxidised nitrogen comes off as nitric oxide, which is measured volumetrically.

2036.—*What is* FRANKLAND *and* ARMSTRONG'S *method of estimating the organic carbon and organic nitrogen?*

FRANKLAND and ARMSTRONG'S process consists in submitting to organic analysis, by combustion with oxide of copper in a combustion tube, the residue obtained by evaporating the water under examination to dryness. The gases—nitrogen and carbonic acid—liberated during the combustion are collected in a graduated tube. The carbonic acid is withdrawn by the aid of caustic potash, leaving the nitrogen, when its volume can be read off. Previous to evaporation, any ntirates or nitrites are destroyed by the addition of sulphurous acid to the water. The above process gives the amount of nitrogen present in the form of ammonia and organic nitrogenous matter. The amount of nitrogen present as nitrates and nitrites is estimated by treating the residue of another portion of the water with strong sulphuric acid in a graduated tube standing over mercury. On agitating the tube, the whole of the nitrogen present in the form of nitrates and nitrites is liberated as nitric oxide, the volume of which is read off and halved for the amount of nitrogen. As the evolution of hydrochloric acid gas, the result of the action of the sulphuric acid on any chloride present, would interfere with the result, all the chlorides are destroyed by the addition of sulphate of silver previous to the addition of the sulphuric acid.

2037.—*Give the outline of* FRANKLAND'S *organic carbon and organic nitrogen process.*

A litre of the water is mixed with 30 C.C. of a freshly saturated solution of sulphurous acid, and boiled for a few minutes. Such a solution of sulphurous acid can be readily and rapidly prepared by passing the gas from a syphon of liquefied sulphur dioxide into distilled water; these syphons are now articles of commerce. By the above treatment the carbonates are decomposed and carbonic acid expelled. When the water contains little or no carbonate, 0·2 gramme of sulphite of sodium are added before evaporation.

2038.—*What advantages does* FRANKLAND *claim for his process?*

Dr. FRANKLAND claims for his process that it is the only one which determines with anything like precision the total quantity of organic carbon and organic nitrogen present in a water, *i.e.*, the carbon in forms other than carbonates, and the nitrogen in forms other than those of ammonia, nitrites, or nitrates; and hence that it affords a measure of the carbon and nitrogen present in the organic matter in a water. In this process the organic carbon is oxidised and obtained as carbon dioxide, and the organic nitrogen is liberated in the free gaseous state and measured. It is further claimed that the proportion of organic carbon to organic nitrogen enables the analyst to judge as to whether the organic matter is of vegetable or animal origin, since animal matters, as a rule, are richer in nitrogen than vegetable matters. But every one of these claims has been vehemently contested.

2039.—*What is the general opinion held regarding* FRANKLAND'S *process?*

In the first place, although it is indubitable that when stable carbon compounds, such as quinine and sugar, are added to a water, the carbon in the latter and the carbon and nitrogen in the former can be determined by the FRANKLAND combustion process with a reasonable amount of accuracy, it is by no means certain that the minute quantities of carbon and nitrogen present in sewage can be determined with anything like the same amount of precision; and it is possible that, during the necessary evaporation to dryness of a large volume of water, unstable and readily decomposable bodies may undergo decomposition, and be lost so far as analysis is concerned. This criticism has never been satisfactorily refuted; and although in a great majority of instances it may have no value, it is probable that in some instances it may have great force. As to the value of the assertion that a higher proportion of nitrogen to carbon is found in animal ,as compared with vegetable matter, the whole validity of the comparison based on the ratios of these two elements present rests upon the assumption that the absolute amounts of carbon and nitrogen are both determined; and, as has been already intimated, this has not been proved. It is remarkable, too, that in sea water the ratio of organic nitrogen to organic carbon is very high indeed—an asserted characteristic of animal, and assuredly of deleterious organic matter. Yet it can scarcely be supposed that the organic matter in sea water is chiefly or entirely noxious animal matter, any more than the organic matter in river water unpolluted with sewage. Yet the FRANKLAND process would *per se* lead us to suppose that sea water is dangerously polluted with animal matter. FRANKLAND'S organic combustion process is one which requires great care and exactitude in its execution. It cannot be entrusted to the hands of any but those accustomed to its working, and skilled in minute gas analysis. Hence it is seldom employed by the Medical Officer of Health.

With reference to FRANKLAND'S method, SANDER says · "Without a knowledge of the previous history of the water, the relative proportion (between carbon and nitrogen) is not available as a means of deciding as to the nature of the contamination; if, however, the previous history of a water is known, there is scarcely need of so particular an analysis in order to judge of its character." For this reason FRANKLAND'S method has not been used to any extent in Germany or in England.

[In general terms it is carried out in two stages which briefly are :—1. For the nitrogen present in the form of ammonia and organic nitrogenous matter—first, destroy any nitrates or nitrites present by means of sulphurous acid, and then evaporate a given amount of the water to dryness; the total residue thus obtained is then heated with oxide of copper in a combustion tube, and the nitrogen and CO_2 collected in a graduated tube. The CO_2 is absorbed by KOH leaving the nitrogen.

2. For the nitrogen of the nitrites and nitrates, treat another part of the water with strong sulphuric acid, and collect the gases in a graduated tube near mercury; the nitrogen comes off in the form of nitric oxide; the volume of this is then halved for the amount of nitrogen.]

2040.—*Do the figures representing the amount of organic carbon and oxygen consumed in the same specimen of water approach one another?*

Frequently they do in a very remarkable manner. Upon this Dr. FRANKLAND states.—In the periodical examination of waters *from the same source*, I have noticed a remarkable parallelism between the proportions of organic carbon and of oxygen abstracted from permanganate of potash. Thus, for many years past, I have seen in the monthly examination of the waters of the Thames and Lea supplied to London such a parallelism between the numbers given by Dr. TIDY, expressing "oxygen consumed," and those obtained by myself in the determination of "organic carbon."

2041.—*What is meant by the total inorganic nitrogen?*

The "total inorganic nitrogen" is the sum of the amounts of nitrogen found in the three forms, nitrites, nitrates and ammonia, and is to be regarded, after certain deductions have been made, as the nitrogen of animal matter which existed in the water at a previous time. But as the inorganic nitrogen is liable to be reduced in quantity if it comes within the reach of the absorbent roots of plants the inferences to be drawn from this previous pollution are less exact than those based upon the evidence of present contamination. As a rule, however, a water which contains anything more than the merest trace of inorganic nitrogen must have been polluted by animal matter at some previous period, and this "inorganic nitrogen" is a measure of the *minimum* amount of such contamination.

2042.—*Is it important to know the nature of the organic matter present?*

Yes; it is very important to know whether the organic matter thus destroyed was of animal origin, and if so, whether the quantity was considerable.

2043.—*How is this information obtained according to* FRANKLAND?

The only item in water analysis which furnishes direct evidence on these heads is the "total inorganic nitrogen."

2044.—*What are the objections to the ignition process as indicating the amount of organic matter ?*

The loss on ignition included with other things than the organic matter as :—

> CO_2 from the $CaCO_3$ if H_2O from a hydrated salt such as sulphate of lime which becomes anhydrous, and if acid from magnesium salts, if they happened to be present in the solid residue—in nitrates NO_2.

2045. —*What is* FRANKLAND'S *opinion regarding the result of the organic carbon and organic nitrogen process ?*

That the extent of contamination of water by organic substances can be satisfactorily inferred from the carbon and nitrogen contained in the organic matter.

2046.—*Does this process show accurately the total organic pollution ?*

No ; the present contamination is rarely the total organic pollution.

2047.—*Is the evidence afforded by the presence of inorganic nitrogen of importance ?*

It may or it may not be. Sometimes it becomes of the utmost significance. " Inorganic nitrogen" becomes at times of the utmost importance in dealing with these waters, for at times when they are most liable to suffer from contamination, the oxidising power of the soil may be inadequate to destroy dangerous matters, and what has hitherto appeared as evidence of past contamination only may suddenly assume the form of present or actual pollution.

2048.—*What amount of nitrogenous organic matter may be allowed in water ?*

There should be practically no *nitrogenous organic matter* in water, the limit of albuminoid ammonia being ·035 of a grain to the gallon, and if there be much *free ammonia*, even this amount of albuminoid ammonia should be viewed with suspicion. [*Animal matter* should always be regarded as injurious to the quality of a water, especially if human excrement is the source of the animal matter. It is most important that all drinking water be free from decomposing organic matter. In such a state organic matter is invariably associated with micro-organisms, which when introduced into the body may give origin to such diseases as cholera and enteric fever. This is particularly liable to occur if the excrement of persons suffering from these diseases gains access to the water, and we know that there are many ways in which this can occur.]*

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*AUTHOR'S *Hygiene of Water and Water-Supply.*

2049.—*What is the limit of organic carbon and organic nitrogen in spring and deep well water laid down by the River Pollution Commissioners?*

·1 of organic carbon.
·03 of organic nitrogen.

2050.—*What is the limit of "organic carbon" and "organic nitrogen" laid down by the Rivers Pollution Commissioners in surface and river water?*

Surface water and river water which contains in 100,000 parts more than ·2 parts of organic carbon, or ·03 parts of organic nitrogen, is not desirable for domestic supply and ought to be rejected if possible.

2051.—*What is the moist combustion process?*

That of completely (or almost completely) oxidising organic bodies by means of permanganates.

2052.—*How is the moist combustion process conducted?*

One litre of the water is placed in a retort. Before beginning to distil, 5 C.C. of the solution KOH are dropped into the water contained in the retort and the 5 C.C. of the solution of permanganate are very carefully measured and likewise dropped into the retort, which is then heated and its contents rapidly distilled until about 900 C.C. have distilled over. That having been done the heating is stopped and the observation is made that the liquid remaining in the retort retain a pink colour. Then 10 C.C. of the solution of H_2SO_4 are dropped into the retort and in a few minutes the liquid will become quite colourless. That having been attained the solution of permanganate of potassium contained in a graduated pepette is carefully dropped into the liquid and the time is accurately noted at which the red colour just begins to be permanent.

2053.—*What data are furnished by this operation?*

1. The total number of C.C. of permanganate used up.

2. The total number of C.C. of permanganate used up by the iron solution.

The difference between these figures is the number of C.C. of permanganate consumed by the organic matter in one litre of water or the number of mgms. of active O consumed by the organic matter in one litre of the water.

If the standard solution of permanganate be added to an acid solution containing permanganate of iron, a point will soon be reached at which the faint pink colour ceases to disappear on shaking up the solution, but after the lapse of a few minutes the pink colour gives place to a brownish precipitate. This last destruction of permanganate is probably due to the formation of ferric acid, but it takes place only after the lapse of time and the only consequence which results is that in permanganate the final readings must be immediate and not after lapse of time.

2054.—*What solutions are necessary for the moist combustion process?*

The solution of permanganates of iron—one C.C. absorbing 1 mgm. of active oxygen, solution of carbonate of potash solution containing H_2SO_4.

2055.—*What apparatus are needed?*

One flask or retort, an arrangement for boiling, a litre measure, a 5 C.C. pepette to discharge 5 .CC., and a 5 C.C. pepette graduated to 0·2 C.C.

2056.—*How is this information obtained according to* FRANKLAND?

The only item in water analysis which furnishes direct evidence on these heads is the "total inorganic nitrogen."

This second general method in anything like common use is a method devised by FRANKLAND and ARMSTRONG; it was used in the great number of examinations published in the Reports of the Rivers Pollution Commission of Great Britain The method consisted in evaporating a given quantity of the water, under carefully regulated conditions, and in submitting the residue to a process of organic analysis by which all the carbon is converted into carbonic acid and the nitrogen is liberated in the gaseous state. The mixture of nitrogen and carbonic acid is then analysed by processes of gas analysis. The results are stated in so many parts of "organic carbon" and so much "organic nitrogen" in 100,000 parts of the water, and sometimes the two amounts together are spoken of as the amount of the organic "elements"

Suppose one litre of the water was placed in the retort, and 5 C.C. of the potash solution and 5 C.C. of the permanganate solution were added. The distillation was then continued till only a small bulk of liquid (100 C.C.) remained in the retort; 10 C.C. of the sulphuirc acid was then added, and 5 C.C. of iron solution, which rendered the liquid quite colourless. When the permanganate solution was run in until a red colour just formed and did not vanish on shaking up: 3·7 C.C. being required for this purpose

We have therefore:—

	C.C.
Total permanganate used	8·7
Permanganate used by the 5 C.C. of iron solution	5·0
Permanganate consumed by the organic matter in litre of water	3·7

Or, one litre of this sample consumes 3·70 milligrammes of oxygen.

2057.—*What is the degree of accuracy of* FRANKLAND'S *and* ARMSTRONG'S *method ?*

It is true that, if we have the amount of organic nitrogen and carbon, we come nearer to having the amount of organic matter than is possible by any other means; but, as has been already said, it is, after all, not the amount, but the character, which is to be considered. In this method of analysis, the character and probable origin are inferred from the *relative proportion* of carbon and nitrogen. Thus, in waters which were rendered impure by the presence of extract of peat, the average amount of nitrogen was to the amount of carbon as 1 : 11 9, while the proportion in sewage was as 1 : 1 : 8.

2058.—*What are the disadvantages of the combustion processes ?*

Combustion processes involve costly and delicate apparatus, and a considerable degree of skill.

2059.—*How may we interpret the results of combustion processes ?*

The significant points are the absolute and relative amounts of organic carbon and organic nitrogen. The lower the proportion of nitrogen to carbon, and the less the amount of each, the more favourable is the verdict, other things being equal. A low proportion of nitrogen to carbon, 1 to 8, indicates vegetable organic matter; a high proportion such as 1 to 3 is pretty certain proof of animal pollution. A river or surface water should not contain more than 0·2 organic carbon or 0·03 organic nitrogen, per 1,00,000. In forming conclusions, due weight must be given to the other analytic data, especially the determination of chlorides and oxidised nitrogen and to the other evidence obtainable, such as the position and surroundings of the source of supply, the facilities for pollution, and the depth and geological characters of the strata from which it is derived.

2060.—*What data give us fairly accurate information regarding the amount of organic matter present ?*

From the amount of the total residue, the quantity left after ignition, the amount of blackening produced, and the odour, a very fair opinion can be formed as to the amount of organic matter present, and whether it is of animal or vegetable origin.

2061.—*According to* FRANKLAND'S *test what is the proportion of C to N in sewerage ?*

It is always less than 3 of carbon to 1 of nitrogen.

2062.—*What should be the proportion of C to N in wholesome water ?*

These never should be less than 7 of carbon to 1 of nitrogen.

2063.—*What is included in the term "total combined nitrogen"?*

Total organic nitrogen and nitrogen, such as occurs in combination with nitrites, nitrates, and ammonia.

2064.—*What may be said as to the relation between the ratio of C to N in water as ascertained by* FRANKLAND'S *method?*

That the lower the ratio of C to N the more dangerous is the quality of the waters, for example, 5 to 1 is far more serious than 10 to 1.

2065.—*How else may the amount of organic matter in water be estimated quantitatively?*

A rough quantitative estimate is obtained by determining the combustible matter in the "total solid residue." Fifty C.C. of sample water are measured into a platinum dish of known weight (A). They are then evaporated to dryness over a water bath in the course of an hour or more, and the weight (B) of the dish and its now dry contents are ascertained, B—A is the weight of the total solid residue, that is, of the organic matter and mineral salts. The dish is next heated to redness, to burn off the organic matter, and weighed again (C) after cooling. The loss on ignition, that is B—C, will give the amount of organic matter in the volume of water taken. The proportion of organic matter per litre, or per gallon, is readily shown from these data.

2066.—*Give an example of the working of this test?*

50 C.C. : 1,000 C.C. :: B—C : X.
Volume taken. a litre. mgrs. lost on ignition.

it being the proportion of organic matter expressed as parts per million, or milligrammes per litre. During ignition the organic matter turns brown, or even black, before disappearing, and if of animal origin it gives off pungent fumes.

2067.—*What is* HORSLEY'S *test for oxidised nitrogen?*

Two C.C. of pure sulphuric acid are added to 1 C.C. of the water, and then a drop of pyrogallic acid solution. A pink or blue tint appears, changing to brown; it disappears momentarily upon shaking, but soon returns.

2068.—*How is the nature of the oxidisable matter in water determined?*

The oxidisable matter in water consist of oxidisable organic matter, nitrites, ferrous salts, and hydrogen sulphide. The last can be easily recognised by the smell and got rid of by gently warming the water. Ferrous salts are rare, but if present they impart a distinct chalybeate taste to the water, if their amount reaches the fifth of a grain of iron per gallon (about 0·3 parts per 100,000). Generally their presence may be disregarded. There remains therefore the oxidisable organic matter, and nitrous acid as nitrites. For determining these, the potassium permanganate is very convenient.

2069.—*Is the distinction between animal and vegetable organic matters in a water an easy matter ?*

No; it is often only made with great difficulty if at all. Generally it may be said that when excess of organic matter in a water co-exists with excessive total solids chlorine and ammonia, the source of pollution in animal filth or sewage. When on the other hand excessive organic matter is not accompanied by excessive total solids, chlorine, and ammonia the source of pollution is probably vegetable; and this diagnosis may be confirmed by the results of physical examination of the water and by microscopic examination of the suspended matters and sediment.

2070.—*What is the best method of determining the organic purity of water ?*

The chemical world is now greatly divided in opinion as to the proper method of determining the purity of water, and chemists are generally ranged on two sides—one agreeing with FRANKLAND and ARMSTRONG in the process which they have devised, and the other preferring the process applied by WANKLYN, CHAPMAN, and on the ammonia process.

In a recent discussion on this subject, it has appeared that many of the practical chemists of the day adopt the latter process, and also that they object to the mode adopted by FRANKLAND in expressing the quantity of nitrogenous elements in water by the phrase, 'previous sewage contamination,' both as implying that the nitrogenous material was necessarily derived from sewage and that nitrogenous material originally derived from sewage may not have become harmless.

2071.—*How does* FRANKLAND *determine the organic matter ?*

As so much organic carbon and organic nitrogen. He detains the organic matter by destroying the molecules by the acid sulphate of soda, and evaporates it to dryness, burns the residue by means of oxide of copper and chromate of lead; the N and CO_2 are then calculated.

2072.—*Is the result obtained as regards the quantity of inorganic nitrogen always correct ?*

It is not, because the quantity of "inorganic nitrogen" at the moment of analysis is often much less than that originally contained in the animal matters which have undergone oxidation. This is sometimes due to the reduction of nitrates and nitrites to elementary nitrogen, by subsequent access of fresh organic matter to the water, and sometimes to the removal by aquatic plants.

2073.—*What is the ordinary test for the presence of oxidisable organic matter ?*

1. Solution $AuCl_3$ ten to one in water boiled for ten minutes gives a pink varying to purple and black. This tells us that there is

oxidisable matter, but not the nature of the matter. Four agents may respond to this test: (1) Oxidisable organic matter in any form; (2) Ferrous salts (unlikely) H_2S or alkaline sulphides, test for each separately; (3) Nitrites and nitric acid (the most probable); we must test for these. This is not a quantitative but a qualitative test.

2074.—*What is meant by the oxygen or* FORCHAMMER *process?*

This process, first suggested by FORCHAMMER, depends upon the estimation of the amount of oxygen which a known volume of the water abstracts from a standard solution of permanganate of potash. With waters of a similar character the oxygen process furnishes a ready and fairly efficient means of comparing their relative organic purity, but it is not trustworthy when waters of heterogeneous origin are submitted to it.

The amount of "oxygen abstracted" can be ascertained with great exactitude and little trouble. It is, however, essential to employ an excess of permanganate, and to allow the action to go on for a considerable time. The amount of permanganate in excess can be accurately determined by the employment of hyposulphite of soda and the iodine and starch reaction, as recommended by TIDY. [The potassic permanganate cannot long maintain its full value, and must therefore be re-standardised at short intervals, whilst the sodic hyposulphite loses strength so rapidly, that its value has to be re-determined by a blank experiment for each set of analyses undertaken.]

2075.—*Does this distinguish the different kinds of organic matter?*

No: for recent sewage, nitrites, H_2S, and ferrous salts, all reduce and discolour the permanganate solution by removing the O.

2076.—*What are the equivalents of the permanganate solution required for the determination of oxidisable matter in water, and what are the other solutions required in the process?*

(*a*) *Permanganate Solution.*

0·395 of potassium permanganate in 1 litre of water.

100 C.C. are exactly decolorised by 100 C.C. of *oxalic acid solution.*

1 C.C. of permanganate solution used with acid yields 0·10 milligramme of oxygen.

1 C.C. of permanganate solution used with alkali yields 0·06 milligramme of oxygen.

1 C.C. of permanganate solution exactly oxidises 0·2875 mgm. nitrous acid (NoO_2).

1 C.C. of permanganate solution exactly oxidises 0·2125 mgm. hydrogen sulphide (H_2S).

1 C.C. of permanganate solution exactly oxidises 0·7000 mgm. iron (Fe).

1 C.C. of permanganate solution exactly oxidises 0·9000 mgm. ferous oxide (FeO).

(*b*) *Potassium Iodide Solution.*—A 10 per cent. solution of the pure potassium iodide, recrystallised from alcohol.

(*c*) *Dilute Sulphuric Acid.*—One *volume* of pure sulphuric acid is mixed with three *volumes* of distilled water, and permanganate solution dropped in until the whole retains a *very faint* pink tint after warming to 80° F. for four hours.

(*d*) *Sodium Hyposulphite.*—One gramme of crystallised sodium hyposulphite dissolved in 1 litre of water.

(*e*) *Starch Solution.*—One gramme of starchto be intimately mixed with ½ litre of distilled water, the whole boiled briskly for five minutes, filtered, and allowed to settle.

2077.—*How is the standard volumetric solution for the oxygen process prepared ?*

Standard volumetric for oxygen process ; 395 grms. of potassic permanganate is dissolved in a litre of water. Each C.C. contains ·0001 grms. of available oxygen.

2078.—*What reagents are essentially required for the oxygen process ?*

A solution of potassium permanganate is required, which in presence of an acid is capable of yielding 0·1 milligramme of oxygen for each C.C.

2079.—*How is the test conducted ?*

Take a convenient quantity of the water to be examined, say 250 C.C. ; add 3 C.C. of sulphuric acid ; drop in the permanganate solution from a burette until a pink colour is established ; warm the water up to 140° Fahr. (60° C.), dropping in more permanganate if the colour disappears ; when the temperature reaches 140° Fahr. remove the lamp ; continue to drop in permanganate until the colour is permanent for about ten minutes. Then read off the number of C.C. used, multiply 0·1 to get the milligrammes of oxygen, and by 4 to get the amount per litre.

2080.—*Give an example of the working of this test ?*

Suppose 250 C.C. of water, with 3 C.C. of sulphuric acid, required 3·5 C.C. of permanganate to give a permanent colour ; 3 5 × 0·1 × 4 = 1·4 milligrammes of oxygen per litre required for *total* oxidisable matter, 1·4 × 0·1=0·14 per 100,000.

It must be remembered that this includes both organic matter and nitrous acid. We must now differentiate these.

2081.—*How may we estimate the organic oxidisable matter in terms of oxygen required for its oxidation ?*

Take 250 C.C. of water to be examined ; add 3 C.C. of sulphuric acid as above ; boil the water briskly for twenty minutes ; allow it to cool down to 140° Fahr. (60° C.) ; then add the permanganate until a pink colour is established for ten minutes. Calculate the oxygen as above, stating the result as milligrammes per litre required for oxidisable organic matter, or, shortly, as *organic oxygen.*[*]

2082.—*From this result how may the amount of oxygen consumed per litre be determined ?*

As a quarter of a litre of the sample was taken for each analysis, four times this result will give the "oxygen consumed" in milligrammes per litre—that is, in parts per million.

2083.—*What reagents are required for the ordinary quantitative test for the total oxidisable matter in terms of oxygen required for its oxidation ?*

A solution of potassium permanganate is required, which in presence of an acid is capable of yielding 0·01 centigramme of oxygen for each C.C.

2084.—*How is the test carried out ?*

Take a convenient quantity of the water to be examined, say 250 C.C., and 3 C.C. of sulphuric acid ; drop in the permanganate solution from a burette until a pink colour is established, warm the water up to 140° F. (60° C.), dropping in more permanganate if the colour disappears ; when the temperature reaches 140° F. remove the lamp, continue to drop in permanganate until the colour is permanent for about ten minutes. Then read off the number of C.C. used and multiply by 0·04 to get the amount per 100,000.

2085.—*Explain the reaction occurring.*

The reaction occurring is that the permanganate of potassium give up oxygen on the addition of the sulphuric acid reducing it to a permanganate of potassium, and forming sulphate of potassium.

2086.—*Give the formula representing the reaction.*

$$2KMnO_4 + 3H_2SO_4 = 2MnSO_4 + K_2SO_4 \times 3H_3O + 5O.$$

2087.—*Suppose no acid was added, what would be the reaction ?*

Only three atoms of oxygen would be set free from the potassium permanganate ; thus,

$$2KMnO_4 + H_2O = MnO_2 + 2KOH \times O_3.$$

2088.—*What is the reaction occurring on the addition of the sulphuric acid and permanganate of potassium to the water ?*

$$2(KMnO_4) + 3(H_2SO_4) = K_2SO_4 + 2(MnSO_4) + 3(H_2O) \times O_5.$$

2089 —*What reaction occurs if the permanganate only is added to the water ?*

$$2(KMnO_4) + H_2O = 2(MnO_2) + 2(KHO) + O_3.$$

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[*] PARKES' *Practical Hygiene*, 7th Ed.

2090.—*Why therefore is the acid added?*

To increase the volume of oxygen set free—one molecule more being evolved on the addition of the acid.

2091.—*How much O is represented in the permanganate solution?*

Each C.C. represents 0001 gramme of oxygen of which one atom oxidises one molecule of NO_2 and NO_3.

2092.—*What is the most convenient and practicable method of determining the oxidisable organic matter in water?*

The permanganate process is the only one that is practicable for medical officers, that gives us any measure of the oxidisable organic matter in water, and is, in the presentstate of our knowledge indispensable, imperfect though its indication may be. It is certainly an aid to our judgment of the condition of a drinking water, being to FRANKLAND's carbon process something the same as the albuminoid ammonia method is to his nitrogen one. FRANKLAND has fully acknowledged this relation in his latest work, and has proposed a series of factors by which to multiply the oxygen absorbed, so as to express the result in terms of organic carbon. These factors are based on the observed relations between the two processes in a very large number of experiments, and are formed by dividing the average carbon by the average oxygen. The factors differ for different kinds of water in the following proportions:—

River water, $\frac{C}{O}$ = 2·38
Deep-well water, ,, = 5·80
Shallow-well water, ,, = 2·28
Upland surface water, ,, = 1·80

so that 1 centigramme of oxygen absorbed indicates a probable amount of only 1·8 of organic carbon in an upland surface water, but as much as 5·8 in a deep-well water.*

2093.—*What precautions are necessary in the permanganate processes?*

The sulphuric acid and permanganate must be added to the water from the very commencement, in order not to lose nitrous acid, which may be driven off as the water is being heated. The faintest tinge of colour that can be distinctly seen ought to be accepted, provided it remains for ten minutes. Care must be taken to add the sulphuric acid in every case at the beginning; if this is not done a brown colour is struck which spoils the experiment. Sometimes this colour appears, even after acid is added, and is then probably due to excess of organic matter; dilution with distilled water sometimes remedies this.

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* PARKES' *Practical Hygiene*, 7th Ed.

2094.—*What should be the limit of oxygen absorbed in a good water?*

This ought not to exceed about 0·0250 per 100,000 for organic matter alone,—that is, after deducting any that may be absorbed by nitrous acid if present. This latter, however, should not be present in a water of the first class. The experiment to be done with permanganate and acid at a temperature of 140° Fahr. (60° C.).

2095.—*What is the method recommended by the Society of Public Analysts for determining the amount of oxygen required to oxidise organic matter?*

Two separate determinations are made—the amount of oxygen absorbed during fifteen minutes, and that absorbed during four hours; both being made at a temperature of 80°F. (26°F. C.). These are made in 12 oz. stoppered bottles. Put 250 C.C. of the water into each of two of the bottles; stopper and immerse in a water bath until the temperature reaches 80° F. Now add to the water 10 C.C. of dilute sulphuric acid (1—3), and 10 C.C. of a solution of permanganate of potassium (0·395 gramme per litre).

Fifteen minutes after the addition of the permanganate, one of the bottles is removèd from the bath, 2 or 3 drops of a solution of the iodide of potassium is added. The quantity used will represent the quantity of theosulphate solution equivalent to 0·00395 gramme permanganate, or ·001 of available oxygen.

The calculation of the results is as follows:—

Let X = number of C.Cs of theosulphate used in the distilled water.

Y = number of C.Cs. of theosulphate used in the water under examination.

Then if 10 C.C. of the permanganate solution were used

$$\frac{X - Y + 0{\cdot}2}{X} = \text{grains of oxygen required to oxidise organic}$$

matter in one gallon of the water.

If 20 C.C. of permanganate were used, 2 X must be substituted for X in the above equation, if 30 C.C. substitute 3 X, and so on, in making the calculation.*

Let a = number of C.C. theosulphate required in blank experiment. C. = 10 C.C. permanganate.

b = number of C.C. theosulphate used in titration of the water.

Then $\frac{a - b \times {\cdot}28}{a}$ = grains of oxygen per gallon required to oxidise organic matter.

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* Journal of Chem. Soc. Trans. Vol. XXXV, 1879, p. 46, quoted in FRANKLAND's *Water Analysis*, 6th Ed

2096.—*Name a particular circumstance under which the "oxygen consumed" is of value.*

In differentiating between water contaminated by sewage and ammoniacal deep spring water.

2097—*What is the object of* TIDY'S *process?*

The object is to determine the amount of oxygen absorbed in 1 hour and 3 hours, respectively.

2098.—*What precaution is to be always adopted?*

As the hyposulphate solution is liable to change, it is necessary to perform a blank test with distilled water every time.

2099.—*What reagents are needed for* TIDY'S *modification of* FORCHAMMER'S *Permanganate process for determination of oxygen required to oxidise organic matter?*

This process is carried out in various ways. The following is the method as advised by Dr. TIDY, who has specially investigated the process

The following solutions are required (for the quantities given by Dr. TIDY in grains and septems are substituted grammes and cubic centimetres):—

1. Dilute sulphuric acid: 1 part of pure sulphuric acid with 3 parts of distilled water.
2. Solution of permanganate of potassium 0·286 gramme per litre, 10 C.C. = ·714 milligramme of available oxygen.
3. Solution of iodide of potassium, free from iodate: 1 part in 10 parts of water.
4. Theosulphate of sodium (hyposulphite): 0·77 gramme in a litre of distilled water.
5. Starch solution, carefully prepared: about $1\frac{1}{8}$ gramme in 100 C.C. of water.

2100.—*What precaution is necessary in this test?*

To see that the KI is pure, and that it does not contain any of the *iodate.*

2101.—*How is* TIDY'S *process carried out?*

Four flasks are employed, two of which contain 250 C.C. of sample water, while the other two contain 250 C.C. of distilled water for the control experiments. To each flask are added 10 C.C. of permanganate solution (A), and 10 C.C. of dilute sulphuric acid (E). If the water is very bad, the pink colour due to the permanganate may soon entirely disappear, and in this event a second and even a third 10 C.C. of permanganate must be added, so as always to have a pink tinge throughout the experiment. At the end of an hour one of the samples and one of the control flasks are tested to ascertain how much undecomposed permanganate remains to be deducted from the total used. For this purpose 2 C.C. of iodide solution (C) are added, and the remaining permanganate immediately acts upon it, liberating a proportionate amount of free iodine. The iodine is measured with precision by dropping in the standard hyposulphite solution until no more free iodine remains, the exact point of disappearance of the last trace of iodine being ascertained by adding 2 C.C. of starch solution (D) near the end of the process, and noting disappearance of the blue iodide of starch.

2102.—*How does permanganate of potash act in this reaction?*

The H_2SO_4 reduces it to a manganese sulphate and potassium sulphate, thus,

$$+3H_2So_4=2MnSo_4+K_2SO_4+3H_2O+5O.$$

If no acid were added the reaction would be:

$$+2H_2O=2MnO_2+2KOH+O_3$$

Therefore without the aid of the acid we only get 3 instead of 5 atoms of oxygen.

2103.—*How do we interpret the results of the oxygen process?*

Not only organic matter, but also nitrites, ferrous salts, or sulphuretted hydrogen will reduce permanganates, and these latter, if present, must be removed or allowed for. No distinction is made between nitrogenous and non-nitrogenous organic matter. In London waters the organic matter is said to be about eight times the "oxygen consumed." It seems that putrescent matters, notably urine and other animal matter, are readily oxidised by permanganate, so that while the three hours' experiment gives information as to the total amount of organic matter, the one hour reaction is important as indicating the proportion of putrescent and, therefore, presumably dangerous impurities. Sometimes four hours are allowed instead of three, and quarter or half an hour instead of one hour. Peaty waters consume much oxygen.

As in all other modes of estimating the organic matter in water, the results of the oxygen process must be considered together with the other analytic data and the source of the water. In a general way, TIDY classifies waters as of great organic purity if the oxygen consumed does not exceed 0 5 part per million, of medium purity if not exceeding 1·5 part of doubtful purity up to 2·0 parts, and as impure, if the oxygen consumed exceeds 2·0 parts per million. Upland surface waters, however, (the organic matters being less likely to be harmful) are judged by a more lenient standard, the degrees of which are double those given above, namely, 1·0, 3·0, and 4·0, in place of 0 5, 1·5, and 2·0.

—*It has been stated that there is a definite relation between the absolute weight of different organic matters and the oxygen they abstract from $KMnO_4$, can this dictum be borne out?*

It cannot. FRANKLAND says: This assumption has been conclusively proved to be entirely fallacious, for it has been experimentally demonstrated by operating upon known quantities of organic substances dissolved in water, that there is no relation either between the absolute or relative weight of different organic matters and the oxygen which such matters abstract from permanganate of potash.

2105.—*What are the ways in which permanganate solution may be used in testing water?*

1. For roughly indicating the amount of organic matter present by the time in which change of colour is produced.

2. In combination with alkalies as alkali permanganate solution, in the albuminoid ammonia process of WANKLYN and CHAPMAN.

3. In the presence of sulphuric acid in which the amount of organic matter is expressed as the amount of oxygen required to oxidize it.

2106.—*Give the late* Dr. TIDY'S *conclusion as to the respective merits of the various processes for the determination of organic matter in water.*

1. As regards the ammonia process, an absolute or nearly absolute freedom from albuminoid ammonia is for the most part an indication of organic purity. Nevertheless, many waters which are very impure give a trace only of albuminoid ammonia, whilst some which are very pure give large quantities of albuminoid ammonia. Its results, therefore, are marked by singular inconstancy.

2. That the ammonia process allows of no sufficiently large scale whereby the finer grades of purity or impurity can be recognised and classified. The errors arising from many causes—such as, amongst others, the ammonia present in the permanganate solution itself, the difference in time required by different organic bodies for their complete destruction, the chances of the organic nitrogen becoming oxidised, the constant multiplication of errors of observation resulting from collecting several distillates in which the ammonia is to be severally determined, and which errors are again doubled in order to convert results into parts per million—form an array of difficulties likely to lead to serious errors, seeing that the range (viz., from 0·05 or 0·1 part per million) between the waters of extraordinary organic purity and dirty waters is comparatively small.

3. That, as regards the combustion process, the necessity for evaporating the water to dryness constitutes a difficulty, the chances being that some of the organic matter, and possibly that subtle form of organic matter specially active in producing disease —the very organic matter, in fact, the detection of which the sanitarian expects from the chemist—may be either mechanically carried off, or volatilised, or oxidised, or even destroyed under the peculiar conditions of the evaporation.

4. That, barring this objection, the estimation of the organic carbon in the water residue is trustworthy, repeated experiments with the same water yielding constant results.

5. That the estimation of the organic nitrogen is by no means so constant, the possibility of the nitrate not being completely reduced, especially when present in quantity; of impurities in the sulphurous acid solution; of occluded nitrogen in the metallic copper; and, lastly, the necessary error of experiment, constituting a series of difficulties which must somewhat impair the nitrogen determination.

6. Under such circumstances, the process can scarcely be considered to yield absolutely trustworthy evidence (unless the organic nitrogen be beyond a certain quantity) on which to found an opinion as to the probable source of the organic matter in the water.

7. As regards the oxygen process, he claims for it that it is conducted on the original water and without the application of heat. Hence we avoid the evils both of gain and of loss arising from, and incident to, the evaporation of the water to dryness at high temperatures. Moreover, the analysis can be conducted with the smallest possible amount of handling, or of pouring the water from vessel to vessel.

8. That the process gives results of great constancy and of extreme delicacy. They admit, moreover, of a very wide scale in their classification.

9. That the oxygen process allows us to draw a sharp distinction between the putrescent or readily oxidisable organic matter, which is the more likely, to use Dr. FRANKLAND's term, to be 'pernicious,' and the non-putrescent or less readily oxidisable matter, which is probably harmless so far as its action on the human body is concerned.

10. That the general inorganic constituents of the water have no action on potassic permanganate.

11. The inorganic constituents most likely to be present in a water that would interfere with the estimation of the organic matter by potassic permanganate are nitrites, metallic protoxides (especially ferrous salts), and sulphuretted hydrogen, all of which are certain to be detected in the course of a proper and complete water analysis, and corrections made accordingly.

12. That in the oxygen process the only modifying circumstances are those which would render the oxygen required by the water excessive, and that therefore, although we might be led to report unfavourably on a harmless water, the results obtained would never lead us to report favourably on a bad water.

13. That whilst he does not consider that the oxygen process can be employed with scientific precision as a direct quantitative test of the total organic impurity of a water, nevertheless the results afforded by it indicate with sufficient precision the comparative quantity present likely to be injurious to health.

14. That the results obtained by the oxygen process must at all times be controlled by the natural history, as well as by the general, chemical, and physical examination of the water.

15. That, so far as the three processes—*viz.*, the combustion process, the ammonia process, and the oxygen process—are concerned, the oxygen and the combustion processes give closely concordant results, whilst the results yielded by the ammonia process are often at direct variance with both. Various arbitrary standards have been laid down defining the amounts of organic matter, as measured by one or other of its elementary constituents, permissible in drinking water. All are more or less unsatisfactory; for it is the kind rather than the amount of organic matter that renders this injurious.

All recent advances in medicine point to the presence of organised organic matter, or possibly definite chemical bodies, the products of changes evoked by organisms, as the potent factors in producing those diseases referable to the use of polluted water.

Hence standards having reference to the quality rather than the quantity of organic matter present in waters are desirable; but no such satisfactory standards have been hitherto devised.

[There are, however, the three modes of detecting, or rather gauging, the quantity of organic matter present in a water already described; and these, by the aid of other data often available, enable the practitioner in public health to arrive at a satisfactory conclusion as to the potability or the probable noxious character of a water.

These methods are the *organic combustion process* of Dr. FRANKLAND, the WANKLYN process, and the permanganate process, respectively, and are commonly known by the names of those chemists, the permanganate process being often referred to as Dr. TIDY's, he having improved upon the older permanganate processes previously used.]

The assessment of the values to be attached to each of the determinations of a water analysis, and the whole determinations collectively, is a subject on which the greatest diversity of opinion has existed among chemists, and which still exists to some extent.

It is chiefly over the determinations of organic matter, and the determinations, such as the *amount of oxygen absorbed* from permanganate, which serve as indexes to the amount of organic matter, though not directly serving as measures of this, that the battle of water analysis has raged most furiously; but most, perhaps, of all as to relative values of the figures obtained by the FRANKLAND combustion and the WANKLYN albuminoid ammonia processes.

A water must be judged—so far as it can be judged by analysis alone—by the whole results of the analysis and not by one constituent, be it organic nitrogen or albuminoid ammonia alone.*

Dr. STEVENSON deprecates the attempt made by the late Mr. WIGNER and by other members of the Society of Public Analysts (Vol. III) to attach a numerical value to the amount of each of one of the important constituents, such as total solids, hardness, chlorine, ammonia, etc., and then to assess the impurity of a water by a summation of those numbers, *e.g.*, saying that the impurity of a water is 20, 10, 17, etc., as the case may be.

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* *A Treatise on Hygiene and Public Health*, by Drs. STEVENSON and MURPHY. Article *Ærated Water*, by Dr. F. STEVENSON.

2107.—*What is considered to be a rough test for recent sewage contamination?*

The "rapid" decoloration of a solution of permanganate of potash. The water is first to be acidulated. The test should be conducted at a temperature of 140° F.

[*N.B.*—This in realty shows the presence of much fresh organic matter, most likely of sewage origin. It should be remembered, however, that the same reaction is given by H_2S, ferrous salts, and nitrous acid (nitrites) in water, the presence or absence of which should be determined and allowed for.]

2108.—*What is the nature of the organic sewage gases which may gain access to water?*

The nature of organic vapours is not exactly known, and their properties have not yet been ascertained. They arise from the decomposition of sewage organic matter, the composition of sewer vapour being principally various undefined carbo-ammoniacal compounds having the odour of putrid animal matter.

2109.—*What is the most dangerous impurities of water?*

Of the hurtful substances the suspended animal, and especially fæcal matters, are probably the worst. At least, it is remarkable how frequently, both in outbreaks of diarrhœa and typhoid fever, the reports notice turbidity, discoloration, and smell of the water. It is this fact which makes the examination of colour and turbidity important. The thoroughly dissolved organic matters appear less hurtful; at least there is some evidence that perfectly clear waters, though containing much matter dissipated by heat, and consisting of dissolved organic matter or its derivatives, are often taken without injury. Probably, also, the more recent the fæcal contamination, the more injurious, since the most poisonous attacks on record have been in cases of wells into which, after slow percolation for some time, a sudden gush of sewage water has taken place.

2110.—*Of animal impurities in water upon what does the degree of danger depend?*

Upon the quality and nature of the animal matter rather than upon the quantity.

So far as chemical analysis can show, the whole of the animal matter may have been oxidised and converted into mineral and innocuous compounds at the time the analysis is made; there is, however, always a risk lest some portion (not detectable by chemical or microscopical analysis) of the noxious constituents of the original animal matters should have escaped that decomposition which has resolved the remainder into innoxious mineral compounds. But this evidence of previous contamination implies much more risk when it occurs in water from rivers and shallow wells than when it is met with in the water of deep wells or of deep-seated springs. In the case of river water there is great probability that the morbific matter, sometimes present in animal excreta, will be carried rapidly down the stream, escape decomposition, and produce disease in those persons who drink the water ; as the organic matter of sewage undergoes decomposition very slowly when it is present in running water. In the case of shallow well water also, the decomposition and oxidation of the organic matter are liable to be incomplete during the rapid passage of polluted surface water into shallow wells.

2111.—*If sewage contamination is suspected, what other investigation should be carried out?*

A qualitative examination should be made for phosphates.

2112.—*Discuss the subject of the danger of decaying organic matter in drinking water.*

With reference to the danger from the presence of decaying organic matter in the drinking water, we must distinguish between the organic matters from different sources. First in importance, no doubt, is excremental matter from human sources. The evidence seems very strong that the dejections of persons who are sick with certain particular diseases may communicate the disease to others if they are taken into the stomach. I do not know that there is any proof that fresh sewage from healthy persons, when largely diluted, is injurious if drunk. We know that fish sometimes gather about the mouths of sewers, and seem to thrive; we know, however, that decomposing sewage drives away the fish and, with our present light we can hardly fail to believe that decomposing excremental matter, even if it contain no specific organic poison, is detrimental to health when taken into the stomachs of human beings.

Next in importance to excremental matter is animal refuse, such as forms the waste from slaughter-houses, wool-pulling establishments, tanneries, etc. In the case of such substances, we have less conclusive evidence of direct effect upon health than in the case of excremental matter; and yet the suspicions against them are so strong that all possible means should be taken to keep them out of the sources of drinking water.

Last in order of importance is matter which is purely of vegetable origin. It is felt that such substances, in their decay, may contaminate the surrounding air so as to be a source of injury to health, and it would certainly be undesirable to have any considerable amount present in a drinking water. It is difficult to see why the products of the decay of all vegetable matters should be innocuous, if the products of the decay of animal matters are injurious; and, in any case of contamination, animal and vegetable substances are associated together and it is impossible to distinguish, with absolute certainty, differences in their action or to say to which of them ill effects are to be ascribed.

2113.—*How may vegetable organic matter be distinguished from animal in water?*

Vegetable organic matter may often be recognised by the slowness with which the albuminoid ammonia comes over, by the absence or small amount of chlorides and of free ammonia, and by microscopic examination of the sediment or knowledge of the source of the supply. Animal pollution is indicated if the albuminoid ammonia comes over rapidly, or if the chlorides or oxidised nitrogen are abundant. Pollution by absorption of effluvia, or by the presence of putrefying masses in the water would, however, be unaccompanied by any excess of chlorides.

Animal matter may be recognised (as a rule) by its being associated with a large amount of total solids, Cl and NH_3, and also by the various microscopical and physical methods employed in water examination.

A water entirely free from organic matter is very rare, although some classes of waters are much more liable than others to be charged with it.

2114.—*What are the pathogenic effects of emanations from streams polluted by fæcal matter.*

Evidence as to disease from this cause is conflicting, due to the varying dilution of fæcal matter, and to the presence or absence of tides, since on the going out of the tide, masses of decaying matter would be left on the banks; the same danger is caused when sewage is washed back by the sea, or when rivers dry up considerably in hot weather. Where such conditions obtain the general health of the people living near must suffer, and should there be present germs of any specific disease, as enteric fever, that disease may be developed.

2115.—*What waters are least liable to animal contamination? What is the relation of C to N in them?*

Upland surface waters are least liable to animal contamination. Collected from bare uncultivated districts, the organic matter contained in them is almost entirely vegetable, and usually peat. The ratio of carbon to nitrogen is always high, the average being 10 : 1. The extremes are, however, very wide, from 4 : 1 to 21 : 1. This is owing to the more rapid loss of carbon than of nitrogen suffered by peaty matter during oxidation, and hence the proportion of carbon to nitrogen is lower in the water of lakes than in that of mountain streams which feed them, whilst in a change from low water to flood, the ratio of carbon to nitrogen in a mountain stream will often mount from the minimum to the maximum of the scale.

2116.—*What course should be adopted in the case of drinking water if polluted by animal or other deleterious impurities?*

Any water which gives indications of having become contaminated with animal or other impurities, and which has hitherto been good and wholesome, should be entirely disused until the source of contamination has been ascertained and removed.

2117.—*What is the nature of the organic matters held in solution by water?*

It consists of soluble animal and vegetable matters which have gained access to the water, and of the products of their decomposition. Little is known of their chemical composition, the variety and complexity of the components being so great as to defy analysis.

2118.—*What degree of pollution in river and other waters would cause you to consider them unusable?*

(*a.*) This question may be answered by giving Prof. FRANKLAND's limitation of impurities of effluent water, which is:—

Every liquid which has not been submitted to precipitation produced by a perfect repose in reservoirs of sufficient dimensions during at least 6 hours; or while having been submitted to precipitation, contains in suspension more than one part by weight of dry organic matter in 100,000 parts of liquid; or which not having been submitted to precipitation contains in suspension more than 3 parts by weight of dry mineral matter, or 1 part by weight of dry organic matter in 100,000 parts of liquid.

(*b.*) Every liquid containing in solution more than 2 parts by weight of organic carbon or 3 parts of organic nitrogen in 100,000 parts of liquid.

(*c.*) Every liquid which when placed in a white porcelain vessel to a depth of 1 inch, exhibits under daylight a distinct colour.

(*d.*) Every liquid which contains in solution in every 100,000 parts by weight more than 2 parts of any metal, except calcium, magnesium, potassium, and sodium.

(*e.*) Every liquid which in every 100,000 parts by weight, contains in solution, suspension, chemical combination, or otherwise more than ·5 of metallic arsenic.

(*f.*) Every liquid which after the addition of H_2SO_4 contains in every 100,000 parts by weight more than 1 part of chlorine.

(*g.*) Every liquid which in every 100,000 parts by weight contain more than 1 part of sulphur, in the state of H_2S or of a soluble sulphuret.

(*h.*) Every liquid having an alkalinity greater than that produced by adding 1 part by weight of KOH to 1,000 parts of distilled water.

(*i.*) Every liquid having an acidity superior to that produced by adding 2 parts by weight of HCl to 1,000 parts of distilled water.

(*j*.) Every liquid exhibiting on its surface a film of petroleum or hydrocarbon, or containing in suspension in 100,000 parts, more than ·5 of such oils. To complete this answer *vide* also table given at p. 392.

2119.—*With reference to the danger from the presence of decaying organic matter in the drinking water, what distinction is it important to recognise?*

The different sources of that organic matter. The evidence seems very strong that the dejections of persons who are sick with certain particular diseases may communicate the disease to others if they are taken into the stomach. We do not know that there is any proof that fresh sewage from healthy persons when largely diluted is injurious if drunk. We know that fish sometimes gather about the mouths of sewers and seem to thrive; we know, however, that decomposing sewage drives away the fish, and with our present light we can hardly fail to believe that decomposing excremental matter even if it contain no specific organic poison, is detrimental to health when taken into the stomachs of human beings.

With a few exceptions, the waters which hold in solution a notable proportion of organic matters putrefy rapidly, and acquire injurious properties. It has been proved that diarrhœa, dysentery, and other acute or chronic diseases, have been determined endemically by the long continued use of the water of ponds, marshes, or wells containing excessive proportions of altered organic matters, either in suspension or in dissolution. The investigations of some English pathologists into the effects of certain well waters upon the health of the population using them, more than confirm the theoretical opinion thus expressed by the French chemists from whom we have quoted.

Leaving out of consideration the question whether animal organic matter in suspension or in solution is the more injurious to health, it would appear that it is the quality rather than the quantity which determines the danger.

With the views which are at present held with reference to the danger from the pollution of lakes and streams by sewage and other refuse substances, the most important part of the sanitary examination of such sources of supply is the inspection of the locality from which the water is to be taken and of the surroundings.

Pollution of water with vegetable matters may be recognised by the vegetable cellular tissue, fungi and moulds, algæ, diatoms, desmids and confervæ. [Amongst the decaying vegetable matter other living forms will be found in abundance on microscopic examination. Thus living organisms, including bacteria, amœbæ, englenæ infusoria (vorticellæ, paramæcia, coleps, stentor, oxytricha), anguillulæ, or water worms, rotifera or wheel animalcules, entmostraca (daphnia pulex (water flea) and cyclops quadricornis), amphipoda isopada and tardigrada (water bears), the larvæ of the water gnat and the pupa forms of other insects, besides many others.]

2120.—*What may be considered reasonably safe water?*

Water, although it exhibits previous sewage or animal contamination, may be regarded as reasonably safe when it is derived either from deep wells (say 100 feet deep) or from deep-seated springs, provided that surface water be carefully excluded from the well or spring and that the proportion of previous contamination do not exceed the limits laid down in No. 1617, page 392.

2121.—*Should we condemn water containing much organic matter?*

Yes, we would at least be on the safe side in doing so. Water containing much organic matter should never be used for drinking purposes without previous boiling; especially is this the case when there is an epidemic or cholera or enteric fever in the town or district. By boiling the water, we reduce to a minimum the possibility of infection. It not only destroys the organic impurities, but also causes a precipitation of much of the dissolved mineral matter.*

2122.—*In regard to the organic matter what facts help us in determining its nature?*

A brief history of the specimen and its source; its depth, whence taken (if a well), geological relations, and distance of nearest sewer or drain.

2123.—*What is the relative impunity or organic and saline impurities of water?*

The *organic* impurities are by far the most important constituents of water, as they are the most powerful in producing disease. The *saline* bodies, when in excess, are not without their injurious effects, but when found they are more or less constant and unvarying, can be determined with accuracy, and the diseases they bring about can be readily and with certainty connected with them. Dead organic matter may give rise to diarrhœa, dysentery, malarial fevers, etc., but living organic matter in the form of specific micro-organisms may bring about specific diseases, such as cholera and enteric fever.*

2124.—*What effect on the gases of water have organic matters?*

The O is decreased, the CO_2 is increased, whilst the N is unaffected.

2125.—*What general conclusion may be arrived at after considering the various tests for organic matter?*

That no water should be judged by the quantity of any one or two constituents which it may contain, but that the composition of a water as a whole should be taken into consideration in passing judgment upon its presumable safety when used as a drinking water, and its admissibility as a source of domestic supply. To rely upon organic carbon, or albuminoid ammonia, or ammonia, or oxygen (from permanganate) consumed, may lead to the rejection of a good, or to the adoption of a bad water.

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* From the AUTHOR'S *Hygiene of Water and Water-Supplies*.

2126.—*How does* DR. FRANKLAND *classify waters?*

According to their organic purity as follows:—Class i, *Upland surface waters*; water of great organic purity, containing a proportion of organic elements (organic carbon and organic nitrogen) not exceeding 0·2 part in 100,000 parts of water; Class ii, *Water of medium purity*, containing from 0·2 to 0·4 part of organic elements in 100,000; Class iii, *Water of doubtful purity*, containing from 0·4 to 0·6 part of organic elements in 100,000; Class iv, *Impure water*, containing more than 0·6 part of organic elements in 100,000.

2127.—*What is the admissible limit of the various kinds of impurity in a first class water?*

A standard as to the admissible limit of the various constituents of a *first class water* can only be general and arbitrary. A first class water may at times contain more of the agents given, but as a rule the amounts laid down should not be exceeded. With reference to such a standard we would state that only slight traces of the following substances are admissible in a water of first quality:—Nitric and nitrous acids and ammonia salts, metallic salts, organic matter, alkaline sulphides and sulphuretted hydrogen. It is extremely rare to find all of these substances absent, yet any thing beyond a trace should be looked upon with suspicion. The admissible limit* of other agents is as follows:—

Chlorine, under 2 grains to the gallon.
Ammonia, „ 3 or 4 „ „
Total solids, „ 8 „ „
Volatile „ 1 „ „
Free ammonia under ·0014.
Albuminoid „ ·0056.
Oxygen for oxidizable organic matter, 0·35.
Fixed hardness under 2°.

2128.—*How does* Dr. FRANKLAND *classify waters as regards their usability?*

Reasonably safe waters.—Water, although it exhibits previous sewage or animal contamination, may be regarded as reasonably safe when it is derived either from deep wells (say 100 feet deep) or from deep-seated springs, provided that surface water be carefully excluded from the well or spring and that the proportion of previous (sewage) contamination do not exceed 10,000 parts in 100,000 parts of water, *i.e.*, the inorganic nitrogen.

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* Such limitations as these are arbitrary and can only be used as a general guide and not as hard and fast quantities of constituents.

Suspicious or doubtful water is :—(1) shallow well, river, or flowing water which exhibits any proportion, however small, of previous sewage or animal contamination; and, (2) deep-well or spring water containing from 10,000 to 20,000 parts of previous (sewage) contamination in 100,000 parts of water, *i.e.*, 0·968 to 1·92 part inorganic nitrogen per 100,000, or 0·678 to 1·344 grains per gallon.

Dangerous water is :—(1) shallow well, river, or flowing water which exhibits more than 20,000 parts of previous animal contamination in 100,000; (2) shallow well, river, or flowing water containing less than 20,000 parts of previous (sewage) contamination in 100,000 parts, but which is known, from an actual inspection of the well, river, or stream, to receive sewage, either discharged into it directly, or mingling with it as surface drainage; (3) as the risk attending the use of all previously contaminated water increases in direct proportion to the amount of such contamination, the water of deep wells or deep-seated springs exhibiting more than 20,000 parts of previous contamination in 100,000 must be regarded as dangerous. River or running water should only be placed in the second class provisionally, pending an inspection of the banks of the river and tributaries, which inspection will obviously transfer it either to the class of reasonably safe water if the previous contamination be derived exclusively from spring water, or to the class of dangerous water if any part of the previous contamination be traced to the direct admission of sewage or excrementitious matters.

2129.—*What amount of organic matter as expressed in the various analytical results, is permissible in water?*

The loss on ignition should not exceed 2 or 3 grains per gallon of water, and the fumes evolved during ignition should have no animal odour. The evolution of ruddy acid vapours indicates excess of nitrites. Albuminoid ammonia should not exceed 0·01 grain per gallon (0·15 per million) except in the case of peaty waters, when the albuminoid ammonia is evolved slowly. Ammonia (so-called 'free' ammonia) ought not to exceed 0·002 grain per gallon, except in the case of an artesian well-water. If the oxygen consumed in the permanganate process exceeds 0·2 grain, or at most 0·25 grain per gallon, the purity of the water is open to grave suspicion. Organic carbon should not exceed 0·3 grain per gallon, nor organic nitrogen exceed 0·03 grain per gallon; and whenever the ratio of organic C to N is less than 5 to 1, the water is open to suspicion.

2130.—*How does* FRANKLAND *classify waters other than upland surface water?*

Class I.—Water of great organic purity, containing a proportion of organic elements not exceeding 0·1 part in 100,000.

Class II.—Water of medium purity, containing from 0·1 to 0·2 part of organic elements in 100,000.

Class III.—Water of doubtful purity, containing from 0·2 to 0·4 part of organic elements in 100,000.

Class IV.—Impure water, containing upwards of 0·4 part of organic elements in 100,000. Nitrogen does not exceed 0·968 part per 100,000, or 0·678 grain per gallon.

2131.—*Is the land drainage from a highly manured soil impure?*

It usually yields a very impure water. The carbonic acid formed during the decomposition of organic matters, whether animal or vegetable, greatly increases the solvent action of these waters upon calcareous matter.

2132.—*How may we distinguish between animal and vegetable organic matter in a water?*

The distinction between animal and vegetable organic matters in a water is often only made with difficulty, if at all. Generally it may be said, that when excess of organic matter in a water co-exists with excessive total solids, chlorine, and ammonia, the source of pollution is animal filth or sewage. When, on the other hand, excessive organic is not accompanied by excessive total solids, chlorine, and ammonia, the source of pollution is probably vegetable; and this diagnosis may be confirmed by the results of physical examination of the water, and by microscopic examination of the suspended matters and sediment.

2133.—*What is the use of a scale of organic purity of a water in interpreting the oxygen process or allied analyses?*

In the interpretation of the results obtained, either by the FORCHAMMER or combustion process, the adoption of a scale of organic purity is often useful to the analyst, although a classification according to such a scale may require to be modified by considerations derived from the other analytical data. It is, indeed, necessary to have a separate and more liberal scale for upland surface water, the organic matter of which is usually of a very innocent nature and derived from sources precluding its infection by zymotic poisons.

2134.—*What is the aluminium process for the determination of oxidised nitrogen?*

For this we require a solution of NaOH absolutely nitrogen free (that is without nitrates), and aluminium free. Two grammes of sodium are dissolved in 100 C.C. distilled water so as to obtain a pure solution of caustic soda free from nitrates; 100 C.C. of sample water are added and a piece of aluminium foil In the course of a few hours all the oxidised nitrogen is converted into ammonia, which is distilled off and Nesslerised. Each mgr. of ammonia, after deducting the free ammonia originally present in the sample, corresponds to 0·82 mgr. of oxidised nitrogen in the 100 C.C. of sample.

2135.—*What is the zinc-copper process for the determination of oxidised nitrogen?*

Zinc foil is coated with copper by exposure to a solution of cupric sulphate until it becomes black. It is then put into a bottle with 250 C.C. of the sample water and 0·5 grm. oxalic acid, and left for twenty-four hours.

2136.—*Do the methods of estimating the amount of organic matters in a water give accurate results ?*

No; they at least only give approximate results ; they are not capable of determining the total amount of such matters in a water. This is a great drawback as the results of one process though perfectly comparable in themselves cannot be compared with the results of another process. There are three processes usually resorted to by water analysts, (*a*) the albuminoid ammonia process (WANKLYN'S), (*b*) the permanganate process, (*c*) the organic carbon and organic nitrogen process (FRANKLAND'S).

2137.—*Discuss the question of pollution from animal refuse apart from human excrement.*

Animal refuse, such as forms the waste from slaughter-houses, wool-pulling establishments, tanneries, etc., may pollute water apart from human excreta. In the case of such substances, we have less conclusive evidence of direct effect upon health than in the case of excremental matter; and yet the suspicions against them are so strong that all possible means should be taken to keep them out of the sources of drinking water.

2138.—*Discuss the question of contact by vegetable matters.*

It is felt that such substances, in their decay, may contaminate the surrounding air so as to be a source of injury to health, and it would certainly be undesirable to have any considerable amount present in a drinking water. It is difficult to see why the products of the decay of all vegetable matters should be innocuous, if the products of the decay of animal matters are injurious , and in any case of contamination, animal and vegetable substances are associated together, and it is impossible to distinguish with absolute certainty, differences in their action, or to say to which of them ill effects are to be ascribed.

Formerly the loss on ignition was looked upon as an important item in the analysis as showing the amount of organic matter in the water. It is in reality valueless.

2139.—*What are the standard quantities of total organic elements oxygen required, and albuminoid ammonia in* ALLOWABLE, DOUBTFUL, *and* IMPURE WATERS.

In upland surface waters they are :—

	Allowable.	Doubtful.	Impure.
Total organic elements .	to ·4	·4 to ·6	over ·6
Oxygen required . . .	to ·3	·3 to ·4	„ ·4
Albuminoid ammonia . .	to ·015	·015 to ·025	„ ·025.
And in all other waters they are :—			
Total organic elements . .	to ·2	·2 to ·4	over ·4
Oxygen required . . .	to ·15	·15 to ·2	„ ·2
Albuminoid ammonia . .	to ·010	·010 to ·015	„ ·015

2140.—*Can the arbitrary standards of purity of different classes of water bear scientific criticism?*

They cannot. Prof. MALLET concludes that there are no sound grounds on which to establish such general standards of purity as have been proposed, looking to exact amounts of organic carbon or nitrogen. Albuminoid ammonia, oxygen of permanganate consumed, etc., as permissible or not. Distinctions drawn by the application of such standards are arbitrary and may be misleading.

Whilst this is perfectly true, considered from the standpoint of scientific precision, it does not sufficiently take into account the value of probabilities in these matters, considered as motives to action. It is perfectly true that there can be no fixed standard that a water which the chemist would report as relatively pure might be much more apt to produce disease than one which he would pronounce impure, but it is, nevertheless, true that from the results of chemical analysis taken in connection with evidence as to the source and history of the water an opinion can be formed as to the danger from its use which is sufficiently reliable to be acted upon in the absence of positive evidence, such as the production of disease.

In many cases the water must be doubtful and Prof. MALLET truly says, that it will not do in all such cases to forbid the use of the water, for it often happens that this should not be done unless it is absolutely necessary, but there are many other cases in which there is very little doubt, and where action should be governed by the probabilities.

CHAPTER XXV.

EXAMINATION OF WATER—*continued.*

NITRATES AND NITRITES.

2141.—*What analyses are conducted in the estimation of oxidisable organic matter and products of organic oxidation?*

Analyses which express their results :—

(*a*) In terms of *oxygen* required for *total oxidisable matter.*
(*b*) In terms of *oxygen* required for *organic matter* only.
(*c*) *Nitrous acid.*
(*d*) *Nitric acid.*

The statement of results is usually given in grains per gallon, or in parts in 100,000; or it may be given in grammes per litre.

2142.—*What are the principles involved in the various quantitative tests for nitric and nitrous acids?*

The nitric and nitrous acids of the salts may (1) be decomposed into nitric oxide, and their amount determined by the quantity of evolved gas; or (2) they may, by the action of nascent hydrogen, be converted into their equivalent of ammonia, and estimated as such; or (3) the nitrates may be estimated volumetrically by the bleaching effect of free nitric acid on indigo.

2143.—*Are the results of examinations for acids and acid radicals always expressed in the same way?*

They are not,—the method of stating the results varies, as in the case of nitrous acid, some reckoning as HNO_2, some as N_2O_3, and others as NO_2. The last is the best, as it corresponds to Cl. In the same way NO_3 is to be preferred for nitric acid, SO_4 for the sulphuric acid, and PO_4 for phosphoric acid.

2144.—*When can an analyst form an unfavourable opinion of water from an estimate of the nitrates?*

Whether or not the analyst should form an unfavourable opinion of the water from the amount of nitrates, must depend upon the proportion of organic matter actually present, and on his confidence in the efficiency and uniform action of the purifying process.

2145.—*What is the process of nitrification?*

One by which nitrogenous organic matter in water or in the soil is oxidised, with formation of nitrates, is due in great measure to the action of microbes or by contact with oxidisable matter, yielding nitrogen or even ammonia.

2146.—*What is the effect of the nitrifying process?*

It renders the nitrogenous matters harmless and fitted for the needs of growing plants, which absorb and utilise the nitrates.

2147.—*What is the term used in representing all these changes?*

Nitrification.

2148.—*To what is the process due?*

Most authorities agree that it is due to the influence of vegetable micro-organisms, and recently two particular forms of microbes have been identified in relation to this process.

Under the influence of these minute vegetable organisms, bacteria, the process of oxidation goes on in different soils at different rates, according to the alkalinity of the soil, amount of moisture, etc.

[The nitrates once formed may be reduced to ammoniacal compounds, or even free nitrogen, so that they alone cannot quantitatively indicate the degree of pollution. FRANKLAND lays great force on these salts indicating previous sewage contamination. Many excellent chemists disagree with him in this respect.]

2149.—*What are the different stages in the oxidising process of the nitrogenous organic matter?*

Starting from fresh sewage material there is:—

(a) Organic nitrogenous matter which when partially oxidised produces

(*b*) albuminoid ammonia. Still later in the process of oxidation we have
(*c*) fully or ready-formed ammonia—free ammonia, NH_3. Following this we have
(*d*) nitrous acid and nitrites; and as a final stage in oxidation we have
(*e*) nitric acid as nitrate.

2150.—*Is the nitrification of animal matter more rapid in the soil that in running water?*

It is; nitrates are formed very slowly in rivers and streams, animal organic matter being oxidised much more slowly in running than in percolating water. They are not formed in waters deficient in dissolved oxygen; and are, if already present, reduced by the addition of more organic matter. Thus they are not usually found in sewage.

2151.—*What are the different forms of combination in which nitrogen may be found in water?*

In any form beginning from actual sewage matter to the fully oxidised products in the form of nitrates—as sewage itself containing nitrogenous organic matter when exposed to oxygen, especially in the soil, gradually oxidises.

2152.—*Are nitrates alone injurious?*

No; they are practically harmless.

2153.—*On what grounds are waters containing nitrates condemned?*

Because nitrates as a rule have sewage as their origin.

2154.—*What is the importance of nitrates in water?*

When water comes into contact with decaying animal and vegetable matters, then carbon, as we have already said, is oxidised to carbonic acid gas, and their nitrogen is oxidised to nitrates, which are dissolved in the water. When this oxidation of organic matter is incomplete in wells, tanks, etc., the water is impure and may be very dangerous to use. Partial oxidation results in the production of *nitrites*. The presence of nitrites in water is always looked upon with suspicion. They are usually contained in water that is sufficiently aerated. When water is undergoing proper aëration, the nitrogen evolved out of organic matter is oxidised into nitrates, and the nitrates into ammonia, with very little formation of nitrites.

Nitrates in any water are always suspicious; but their import varies with the circumstances under which they occur. A minute quantity of ammonium nitrate is present in nearly all waters; and the water of deep springs, which is, as a rule, perfectly free from sewage, may be highly charged with nitrates. Again, if in water containing nitrates, any vegetable growths are present, the nitrates will speedily disappear, having become assimilated by the plants. The absence of nitrates is therefore no proof of the absence of sewage

(WANKLYN). Nitrates represent a completely oxidised condition of the nitrogenous matter of sewage. Sewage in an unoxidised condition might possibly therefore contain only a trace of nitrates.

Almost all waters contain a certain amount of either nitrate of sodium (cubic nitre), or nitrate of potassium (saltpetre), or nitrate of lime (calcareous nitre). Nitre is an oxidised product of decomposed dead animal and vegetable matter. In the quantities in which it is usually found, it is not only not harmful, but probably beneficial to man and animals using the water, and it forms part of the food of all plants, the juices of which invariably contain some of it.

Many excellent waters have been condemned as unwholesome on account of the nitrates contained in them, although it cannot be too strongly insisted upon that the nitrates afford no data of any value in judging of the organic quality of a water.

2155.—*What does the existence of nitrates or nitrites in water point to?*

The presence of nitrates or nitrites in a water is evidence that there has been previous contamination with albuminious matter of some kind, and that such matter has been so far oxidised. They do not indicate, however, that the whole of the oxidation of the nitrogenous impurities has taken place, and on this account their presence should always be regarded with suspicion, especially in a water at all likely to be contaminated with sewage.

Nitrites are often present when not injuriously so, it is an indication of previous (not recent) contamination, and Dr. FRANKLAND says of "original sewage," we do not condemn water with nitrates only, but if abundantly present with chlorine in addition, it is almost certainly contaminated nitrates, alone nitrates do not matter much.

Prof. PARKES' states:—The significance of these nitric and nitrous acids in nitrates and nitrites is very important. Nitric acid is the ultimate stage of oxidation of nitrogenous organic matter and when present in water it is almost always the result of previous pollution, either of the water itself or of the strata through which it flows. It gives us no information, however, as to the exact time when the pollution took place. In some samples from deep wells it is evident that the pollution must have been very ancient. It has been distinctly shown by SCHLOESING and MUNRZ and by R. WARINGTON that nitrification is a feromentative process, excited and carried on through the agency of a minute organism, just as ordinary fermentation is carried on through the medium of *torula*. Nitrous acid indicates the presence of organic matter undergoing change: it is either a stage in the direct oxidation of such matter, progressive or arrested, or a retrogression from nitric acid in consequence of the latter having yielded up a part of its oxygen. In this way nitrous acid might retrograde still further and become converted again into ammonia, or be dissipated as nitrogen. Nitrous acid is a much more important substance than nitric, as indicating present danger, and a very small amount of it is sufficient to remove a water into the suspicious class. It is rare to find any of the higher forms of life in a water rich in nitrites, although *bacteria* may be found. Pure water ought to be quite free from nitrites, and ought to show only traces almost of nitrates,—the limit being about 0·032 per 100,000 of nitric acid,—representing of combined nitrogen 0·014 per 100,000. The total combined nitrogen (including that in the free ammonia) would be 0·016 per 100,000; whilst the total nitrogen (including that in the albuminoid ammonia) would be 0·023 per 100,000. The *presence* of nitrites is suspicious: the marked presence of nitrates ought to be a ground for careful inquiry. In some soils, especially sands and gravels and in ferruginous soils, the process of nitrification goes on extremely rapidly, and the existence of impurity may escape notice if the examination for nitric acid be omitted*

2156.—*Hygienically in what light do we look upon nitrates and nitrites?*

That these are the oxidised residues of organic matters possibly derived from an animal source (sewage). Their determination is therefore a point of the greatest importance, for they indicate either a pollution of the water at some remote period with possibly dangerous ingredients, or the contamination of the water at the present time with partially or completely purified sewage. They are found often in considerable quantities in deep well or spring waters, and in this case merely indicate the complete purification which the water has undergone in its passage from the surface to the subterranean reservoirs. In the case of shallow well waters nitrates and nitrites if found in association with excess of chlorine and ammonia, indicate soakage of sewage or animal refuse into the well, more or less purified by its passage through the intervening layers of earth. At any time, however, the purifying power of the filtering earth may be exceeded or overcome, and then the liquid filth may pass into the well with its dangerous ingredients unchanged and unpurified. Nitrates and nitrites are not present in raw sewage; but they are found in polluted streams and water-courses where a certain amount of oxidation is always in progress and in the effluent subsoil waters from manured or sewaged land. They exist as nitrates and nitrites of lime, soda, potash, etc.

2157.—*Are nitrates and nitrites present in fresh human excrement?*

Nitrates and nitrites are not present in raw sewage or fresh human excreta; but they are found in polluted streams and water-courses, where a certain amount of oxidation is always in progress, and in the effluent subsoil waters from manured or sewaged land. They exist as nitrates and nitrites of lime, soda, potash, etc.

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*PARKES' *Practical Hygiene*, 7th Ed.

2158.—*On the whole then does the estimation of the nitrates alone afford much trustworthy information as to the quality of the water ?*

It does not, for the presence of abundance of nitrates does not necessarily show defilement by means of sewage, and deficiency of nitrates does not show absence of defilement.

2159.—*What do nitrates indicate ?*

As a rule they point to long anterior animal contamination, but under certain circumstance, where, for instance, the contamination is in surface soil containing multitudes of the nitrifying organism, the production of nitrates may be comparatively speedy.

2160.—*What have recent experiments shown with regard to the indications of the presence of nitrates ?*

Dr. FRANKLAND maintains that nitrates indicate previous in the sense of remote contamination, but Dr ASHBY and Mr. HELMER have shown that such pollution may be very recent when bacterial agency is active. The more advanced the putrefaction of the organic matter, the more easily is it oxidised or converted into ammonia, and some authorities think the more injurious, but actually living organisms will naturally be the most refractory, and at the same time may yield but a very small amount of nitrogen or ammonia, although highly dangerous if specific. Shortly, a mere trace of albuminoid ammonia derived from enteric or cholera stools teeming with bacteria may be more dangerous than a hundred times the weight of healthy fæces, or other animal or vegetable matter.

2161.—*What is the origin of nitrates and nitrites in waters ?*

Nitrates and nitrites, perhaps in every proportion, but certainly in any quantity beyond a trace, must be derived from animal or vegetable matters, and so far excites a suspicion of their injurious qualities. If water shows a marked quantity of nitrous acid it is bad, for it can only occur from active decomposition. [If there be a preponderance of nitrates with little reaction to Condy's fluid, there has probably been old sewage pollution. If there be nitrites, ammonia, etc., and there be well-marked action on Condy's fluid, it marks recent pollution with sewage.

2162.—*In what form are the nitrates usually found ?*

As nitrates of potassium (KNO_3), of sodium ($NaNO_3$), of potassium (KNO_3), and of calcium ($Ca(NO_3)_2$).

2163.—*Is it often necessary to differentiate between the nitrates and nitrites ?*

It is not; in fact, it is very rarely necessary to distinguish between nitrites and nitrates in water. If, however, the "Oxygen" or "FORCHAMMER" process is employed to estimate the organic pollution, it is desirable to have a delicate means of testing for and estimating traces of nitrites. One part of sodic nitrite deoxidises about twenty times as much potassic permanganate as an equal quantity of urea, creatin, or starch. The practice, suggested by the late Dr. TIDY, of considering the permanganate reduced by a sample of water within three minutes to be due to nitrites, is not satisfactory; for a sample of sewage free from nitrites reduced in that time as much permanganate as Thames water did in three hours.

2164.—*What are the various tests for the presence of nitrites or nitrous acid?*

[All the preceding tests are for nitrates and nitrites alike. The following apply to nitrites only :—]

1. The water is acidulated by sulphuric acid and a few drops of sulphanilic acid solution are added. Ten minutes later a few drops of naphthylamine hydrochlorate solution are stirred in the water, and a rose tint, changing to orange, will appear if nitrites are present to the extent of 10 parts per million.
2. One drop each of phenol and sulphanilic acid solution, and then ammonia, will give a yellow colour.
3. The addition of starch solution, potassic iodide solution, and dilute sulphuric acid causes a blue tint, due to liberation of iodine by nitrous acid and consequent formation of iodide of starch.
4. Meta-phenylene diamine solution with dilute sulphuric acid (a few drops of each) will give a red colour.

2165.—*What is the simplest test for nitrous acid?*

That by the action of iodine on starch. If any is present by adding KI solution the H_2SO_4 sets free the iodine which is shown by the blue with starch. We make it acid first by H_2SO_4, to separate the nitrous acid from its base.

2166—*What are the three steps in this test?*

(*a*) Add H_2SO_4 sets free acid from base.
(*b*) Add KI, iodine sets free the nitrous acid.
(*c*) Add solution of starch it is turned blue.

2167.—*How may the quantitative estimation of the nitrites be rapidly carried out?*

By means of solutions of meta-phenylene diamine and sulphuric acid, producing a red colour, which is to be compared with a standard as in the Nessler process (GRIESS), or they may be determined by the permanganate process.

2168.—*Describe the napthylamine test?*

The water is first treated with sulphuric acid, acidified, and a solution of hydrochloric acid or sulphate of napthylamine added. A minute trace of nitrite strikes a pale pink; if much nitrite be present there is a ruby colour produced and the solution becomes turbid from the separation of colouring matter.

2169.—*What is the simplest test for nitrates ?*

Make a mixture of 1 part of potassium iodide, some of starch paste, and about 500 parts of boiling water acidulated with a little acetic acid. Add a little of the mixture, which should be quite clear, to the water; a blue tint indicates nitrites. If the colour is at all deep, the water is scarcely safe to drink.

2170.—*What is the best test for the presence of nitrites ?*

That known as GRIESS', as modified by WANKLYN and CHAPMAN and others, and called the *meta-phenylene diamine test.*

2171.—*Is this a delicate test for nitrites ?*

Yes, for besides being easy of execution, it is a test of excessive delicacy, being capable of detecting one part of nitrous acid in thirty million parts of water.

2172.—*Of what does it consist ?*

The method consists in the observatiou of the depth of colour developed in 100 C.C. of the water under examination on the addition of 1 C.C. of a solution of meta-phenylene diamine and one of dilute sulphuric acid; a comparative observation being made on a standard solution of sodic nitrite, as in the estimation of ammonia by the Nessler test.

2173.—*What is the only reliable test for the estimation of nitrites ?*

GRIESS' process, as elaborated by various analysts, is the only trustworthy one for estimating nitrites.

2174.—*What solutions are required for the estimation of nitrites by* GRIESS' *method ?*

The solutions required are:—(1) meta-phenylene diamine,—5 grams. in a litre of water, made acid with sulphuric acid; decolorise if necessary with animal charcoal; (2) dilute sulphuric acid, one part to two of distilled water; and (3) a solution of pure potassic nitrite, prepared from silver nitrite and potassic chloride,—strength ·01 milligram NO_2, or nitrous anhydride per cubic centimetre. To prepare this last solution, dissolve 0·406 gram. of pure and dry silver nitrite in hot water, and decompose it with a slight excess of pure potassic or sodic chloride until no more argentic chloride is thrown down. After cooling, make up the solution to one litre, allow the chloride of silver to settle, dilute each 100 C.C. of the clear supernatant liquid again to one litre. This solution should be kept in closely stoppered bottles quite full.

2175.—*What apparatus is required for* GRIESS' *process ?*

1. Four narrow cylinders of colourless glass, in which 100 C.C. of water should rise to a height of 16 to 18 C., and which must be marked with a diamond at this point.

2. A graduated burette or pepette for the dilute sulphuric acid, and another for the solution of meta-phenylene diamine.

2176.—*What is the best direct method for determining nitrous acid and how is it carried out?*

That of GRIESS'. It is carried out as follows:—A solution of meta-phenylene diamine is prepared, and also a dilute sulphuric acid, consisting of one volume of strong acid to two of water. One C.C. of each solution is added to 100 C.C. of the water to be examined, which is put in a Nessler glass: a red colour is produced. Another glass is placed alongside, and into it are put as much of a standard solution of potassium nitrite as may be necessary, making up the bulk to 100 C.C. with distilled water; then add 1 C.C each of the sulphuric acid and the meta-phenylene diamine. The remainder of the process is carried on much in the same way as ordinary Nesslerising for ammonia. Care must be taken that the water originally taken is not too strong, so if the red colour be too deep, smaller portions diluted up to 100 C.C. must be taken, until the faintest tint distinctly recognisable is obtained. The standard potassium nitrite, should be of the strength 1 C.C. = 0·01 milligramme of NO_2, or nitrogen tetroxide. The number of C.C. used gives the milligrammes of NO_2 present in the sample of water.

The above is now accepted as the most accurate method of determining nitrites, but some care is required,—for both the water and the colouring solution must be either colourless or be decolorised. It may not be always possible to get the reagents, and then it is best to fall back upon the determination of nitrous acid by the permanganate process.

2177.—*Give an example of the method of carrying out the calculations involved in this test.*

Suppose a sample of water containing a good deal of nitrous acid was taken, and 25 C.C., made up to 100 C.C. with pure distilled water, were put in a Nessler glass. 1 C.C. of the sulphuric acid and 1 C.C. of the solution of meta-phenylene diamine added: a distinct red colour was obtained. Into another Nessler glass 7·5 C.Cs. of the standard potassium nitrite were put, made up to 100 C.C. with distilled water, and the same shade of tint obtained with the solutions as above.

Mgm.

7·5 × ·01 = 0·075 NO_2 in 25 C.Cs.

0·075 × 4 = 0·300 NO_2 in 100 C.Cs.

This equals 0·3 in 10,000 or 0·21 in 1 gallon; multiplying any of these results by 0·304 gives the amount of nitrogen (N), that being the factor obtained from its atomic weight.

2178.—*What is the meta-phenylene diamine test?*

The solution is made by dissolving 5 grms. of meta-phenylene diamine in 100 C.C. of water and slightly acidifying with sulphuric acid. A C.C. of the reagent added to 50 C.C. of water strikes a pale yellow to a deep orange red, according to the quantity of nitrite present.

2179.—*Describe what is known as* MELDOLA'S *test.*

MELDOLA'S test is a solution of para-amido-benzene-azo-dimethy-aniline in water acidified with hydrochloric acid (strength about ·02 per cent.). The reagent is added to the water to be tested, the whole acidified with sulphuric acid, warmed for 15 minutes on the water bath, and then alkalised with ammonia. If nitrites are present, the liquid becomes salmon-coloured when acid ; and when alkalised with ammonia green with small quantities, and blue with large quantities of nitrite.

2180.—*Why should waters containing nitrites be examined as soon after collection of the sample of water as possible ?*

Because nitrites, when present in water, are soon oxidised to nitrates.

2181.—*What is the qualitative test for nitric acid as nitrates in water ?*

Mix a little of the water with twice its bulk of pure sulphuric acid. This sets free the nitric acid from its combinations ; then add a few drops of the solution of brucine—a pink and yellow zone occurs at the junction of the water and acid. The sulphuric acid should be poured down the test tube gently, so as to form a layer beneath the mixed water and brucine solution. Half a grain of nitric acid to a gallon gives a marked pink and yellow zone. This is a very delicate test. Another method is to evaporate down two cubic centimetres of water to dryness, add a drop of pure sulphuric acid and a minute crystal of brucine (see next answer). The same reaction takes place, and by it ·01 of a grain to the gallon can be easily detected. In the above test, if a solution of pyrogallic acid be employed instead of that of brucine, a pink zone, turning purple, will be observed.

2182.—*Give a very simple test for nitric acid.*

Put water for about 2 inches deep into a test tube, and pour down by side a little strong sulphuric acid *gently*, and *wait till heat* generated by the acid subsides. Now we may use the *sol. of brucine* which gives first a *pink*, rapidly *passing to yellow*. This indicates nitric or nitrous acid, *or* a similar result arises from a solution of a proto-sulphate of iron which gives an olive colour.

2183.—*How is the brucine solution made ?*

By dissolving 1 gramme of brucine in 1000 C.C. of distilled water.

2184.—*May this test be used in another manner ?*

Yes ; by mixing a crystal of brucine with a drop of H_2SO_4 on a watch glass, and then let a drop of water run down into it.

2185.—*Give another test for nitrates.*

The water is concentrated and mixed with a solution of indigo and sulphuric acid, the presence of nitrates is indicated by a pink and blue color.*

2186.—*What test is employed to detect nitrates in water?*

There is no qualitative test for nitrates not shared with nitrites; in the absence of nitrites the diphenylamine test is very convenient. Diphenylamine is dissolved in a little water by the aid of strong sulphuric acid. A few drops of the solution are added to 10 or 20 C.C. of water and double the volume of sulphuric acid. A purple blue colour denotes presence of nitrates.

2187.—*What are the two most convenient methods for the estimation of nitric acid in water?*

Nitric acid may be determined in several ways, but four seem more easily applicable than the others, viz., 1, SCHULZE's aluminium method (modified by WANKLYN and CHAPMAN); 2, the copper-zinc process; 3, the phenol sulphuric method, and 4, the indigo-carmine method.

2188.—*Upon what do the first two methods depend?*

Upon the conversion of the nitric acid into ammonia.

2189.—*What is meant by the aluminium method, and how is it carried out?*

According to this method, nascent hydrogen is liberated by the action of strong solution of soda or potash on aluminium foil. 100 C.C. of the water should be introduced into a distilling flask, along with 10 C.C. of a solution of sodic hydrate, free from nitrates and boiled briskly until reduced to about one-fourth. It is then made up to its original bulk with water free from ammonia, and when quite cold a piece of aluminium foil about 2 inches square is dropped in.

The aluminium foil is prevented from floating by rolling it round a piece of clean glass rod. The hydrogen, as it is given off, escapes by the distilling tube; and to prevent loss of ammonia, the opening is properly guarded.

2190.—*What is* SCHULTZE's *modified method for the determination of nitric and nitrous acids?*

By this method both are converted into ammonia by the action of aluminium on an alkaline solution; the ammonia is then distilled off, and the amount determined by Nessler's solution. The reagents required are a solution of caustic soda and sheet aluminium.

For the nitrogen of the nitrites and nitrates, treat another part of the water with strong sulphuric acid, and collect the gases in a graduated tube near mercury; the nitrogen comes off in the form of nitric oxide; the volume of this is then halved for the amount of nitrogen.

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* There are no tests for nitric acid or nitrates that are not shared with nitrites (PARKES).

2191.—*What is the principle of the aluminium* (SCHULTZE'S) *process for the quantitative estimation of nitric acid?*

That by converting the acid into ammonia with aluminium in an alkaline solution, the ammonia may be distilled off and estimated in the ordinary way by NESSLER'S solution.

2192.—*How is* WANKLYN'S *and* CHAPMAN'S *modification of* SCHULTZE'S *method for estimating the nitrates and nitrites present in water carried out?*

About a pint of the water to be tested is placed in a retort, and a definite quantity of strong pure caustic soda solution added, and the whole distilled till all the ammonia has been driven off. The contents of the retort are now left to cool, and a piece of thin sheet aluminium introduced, and allowed to remain for four or five hours. Hydrogen is evolved from the metallic aluminium, which, being in the nascent state, unites with the nitrogen of the nitrates and nitrites present to form ammonia. After the action has ceased, the contents of the retort are again distilled, and the ammonia given off estimated by NESSLER'S test. The ammonia thus obtained is an index of the amount of the nitrates and nitrites present. From this result the amountof the acids present may be readily calculated.

2193.—*What is the zinc-copper couple?*

It is an electrical pair formed by the intimate contact of the metals zinc and copper without however the production of an alloy.

2194.—*How may we make the wet copper zinc-couple?*

Put into a flask or bottle a piece of clean zinc foil, and cover it with the copper solution: allow the foil to remain until it is well covered with a firmly adhering black deposit of copper. (If left too long the deposit may peel off in washing) Pour off the solution (which may be kept for further use), and wash the conjoined metals with distilled water. The couple is now ready for use. About one square decimetre (= $\frac{1}{6}$ of a square inch) should be used for every 200 C.C.s of a water containing 5 parts or under of nitric acid in 100,000. For waters richer in nitrates more will be required.

2195.—*What is the zinc-copper couple method, and how is the couple prepared?*

"This method depends upon the electrolytic reduction of nitrates to ammonia by means of a couple of the two metals copper and zinc, which is prepared as follows:—A mixture of 2 grains of finely-divided reduced copper with 18 grains of coarse zinc filings is introduced into a 2 oz. flask fitted with a cork, through which passes a tube drawn out to a capillary opening. The flask is heated over a burner till the zinc begins to soften, shaking gently all the time to ensure thorough mixture of the two metals and to prevent any part being over-heated. The mass, when the operation is finished, should consist of greyish-black grains, without metallic lustre. If the mass has a brassy tint, or if the zinc filings retain their form, the product must be rejected. As soon as the desired result is obtained, the flask is removed from the flame, continuing the agitation for a few seconds to prevent fusion. The point of the capillary tube is then sealed, and the flask allowed to cool."

In this analysis 250 C.C. of the water may be evaporated over a naked flame to about the volume of 25 C.C., a fragment of quicklime about the size of a hemp seed added and renewed till the bulk is reduced to 6 or 7 C.C. The whole is then rinsed into an 8 oz. distilling flask, and the requisite amount of zinc-copper couple added. The flask is closed with a cork, and attached to a small Liebig's condenser, and the water nearly all distilled off. Hot distilled water is added at intervals, and the distillation renewed till 100 C.C. of distillate is obtained. *This, after appropriate dilution of a fraction, say 5 C.C., made up to 50 C.C., is then Nesslerised.*

2196.—*How may the process be rapidly carried out?*

By means of a piece of pure zinc foil and a 3 per cent. solution of sulphate of copper. The action is allowed to go on till a distinct coating of copper is deposited on the zinc: the presence of oxalic acid hastens the process.

The zinc foil coated with the copper is put into a bottle with 250 C.C. of the sample water and 0·5 gram. oxalic acid, and left for twenty-four hours. As in the aluminium process, all the oxidised nitrogen is converted into ammonia and measured as such by Nesslerising.

2197.—*Describe another method for carrying out the estimation by the copper-zinc couple.*

Pieces of clean zinc foil, well crumpled, are immersed in a solution of copper sulphate (3 per cent.); when the zinc is coated, the liquid is poured off, the couple is washed with a little distilled water, and then any convenient quantity of the water poured on to the couple and the whole allowed to stand in a warm place over-night. The water may be distilled, and the ammonia estimated, subtracting what has been previously found as "free" ammonia, but in most cases the ammonia may be estimated directly by taking 10·25 C C. of the water, diluting it up to 100 C.C. and then Nesslerising direct Here again the same correction for ammonia pre-existing will have to be made.

2198.—*What is the simplest method of carrying out the estimation of the amount of nitrates in water?*

Evaporate 10 C.C. of the water in a small platinum dish to dryness. To the residue add 3 C.C. of solution of sulphuric acid and phenol, and two drops of pure hydrochloric acid, and then warm the dish for 3 minutes over the water bath. Pour the contents into a Nessler glass and neutralise with caustic potash solution until effervescence ceases ; then fill up with distilled water to the 50 C.C. mark and compare the depth of the yellow colour produced with that of a test solution containing one milligramme of nitrate of potash in each cubic centimetre to which the same reagents have been added and which has been submitted to a like process. [The process of comparison by depth of colouration is known as "Nesslerising."]

2199.—*What is the yellow colour due to?*

The yellow colouration is due to the formation of picric acid (tri-nitro-phenol), produced by the action of sulpho-carbolic acid on nitric acid. To express in terms of nitrogen as nitrates, the result must be multiplied by 0·14.

2200.—*What is the phenol-sulphuric acid method?*

This method is simple in its application, and yields good results. Phenol-sulphuric acid is prepared by melting absolute phenol, and pouring two parts, by measure, of the liquefied phenol into five volumes of pure concentrated sulphuric acid free from nitrates, when the whole is digested for eight hours in a water bath kept boiling. The mixture is then allowed to cool, and to each two volumes of the liquid is added one and a half volumes of distilled water, and half volume of pure strong hydrochloric acid solution. The light brown solution thus obtained is ready for use.

2201.—*What is the method of carrying out this test?*

Ten C.C. of the water under examination and 10 C.C. of a standard solution of nitrate potassium (0·7215 gramme per litre) are pepetted into two small beakers, and placed near the edge of a hot plate. When nearly evaporated, they are removed to the top of the water-oven and left there till they are evaporated to complete dryness. As this operation usually takes an hour and a half, it is better, when time is an object, to evaporate to dryness in a platinum dish over steam. The residue in each case is then treated with 1 C.C. of the phenol-sulphuric acid, and the beakers are placed on the top of the water-oven. If the water under examination contains a large quantity of nitrates, the liquid speedily assumes a red colour, which in a good water, will not appear for about ten minutes. After standing for fifteen minutes the beakers are removed, the contents of each washed out successively into a 100 C.C. measuring-glass, a slight excess (about 20 C.C.) of ammonia solution (sp. gr. 0·96) added, the 100 C.C. made up by the addition of water, and the yellow liquid transferred to a Nessler glass (6 in. × 1½ in.). The more strongly coloured liquid is then partly transferred to the measuring glass again, and the tints compared a second time. In this way the tints are adjusted, and, when as far as possible matched, the liquid that has been partially removed is made up to the 100 C.C. mark with water and, after well mixing, finally compared. If not of exactly the same tint, a new liquid can at once be made up, probably of exactly the same tint, as the first experiment gives very nearly the number of C.Cs. of the one equivalent to the 100 C.Cs. of the other. Each 1 C.C. of the nitrate solution used = 0·0001 gramme (N).

In the case of very good waters, 20, 50, or more C.Cs. should be evaporated to a small bulk, put into a small beaker, and evaporated to dryness, and treated as above—only 5 C.C. of the standard nitrate of potassiun (= 0·5 N in 100,000) being taken. In the case of very bad waters, 10 C.C. should be pepetted into a 100 C.C. measuring flask and made up to the mark with distilled water, then 10 C.C. of the well-mixed liquid (= 1 C.C. original water) withdrawn, and treated as above.

2202.—*What is the quickest method of estimating the nitrates in solution?*

By indigo-carmine. It is fairly accurate when the nitrates are in quantities, such, for example as over a grain per gallon, but save with special precautions it is not a good method for the estimation of small quantities.

2203.—*How are nitrates partially removed from natural waters?*

Nitrates are absorbed by vegetation, and may therefore be partially or completely removed when the water containing them flows over growing plants.

2204.—*What amount of nitrates is contained in waters from various sources?*

The amount of nitrates in rain varies with the locality, being greatest near towns. Seventy samples from Rothamsted (25 miles from any large town) showed nitrogen as nitrates from *nil* to ·04 approximately, with an average of ·007 in 100,000 parts of water. Upland surface waters are commonly free from nitrates and nitrites, or contain but a mere trace. In them the range of nitrogen in this form is from *nil* to about ·05, with an average of about ·009 part. Surface waters from cultivated districts show an average of ·25 part, ranging from *nil* (which occurs but seldom) to 1 part.

2205.—*What is the hygienic importance of nitrates in drinking water?*

Nitrates in any water are always suspicious, but their import varies with the circumstances under which they occur. A minute quantity of ammonium nitrate is present in nearly all waters, and the water of deep springs, which is, as a rule, prefectly free from sewage, may be highly charged with nitrates. Again, if in waters containing nitrates, any vegetable growths are present, the nitrates will speedily disappear, having become assimilated by the plants. The absence of nitrates is, therefore, no proof of the absence of sewage. Nitrates represent a completely oxidised condition of the nitrogenous matter of sewage. Sewage in an unoxidised condition might possibly therefore contain only a trace of nitrates.

It is however a noticeable fact, that many good and healthful drinking waters contain much nitrites and nitrates, and hence, however harmful may be their origin, they are themselves harmless.

2206.—*How do we account for the large amount of nitrites, nitrates, NH_3 in the surface soil?*

Urea of urine is readily converted into carbonate of ammonia ($CH_4N_2O+2H_2O = (NH_4)_2CO_3$); animal matters in putrefying give off nitrogen which forms NH_3 with H in the soil; thus NH_3 is oxidised sooner or later into nitrous or nitric acid in the form of nitrites and nitrates. [N.B.—Water defiled by animal impurities may contain free ammonia, common salt, nitrites and nitrates.]

2207.—*Why is it customary to determine the amount of ammonia and of nitrogen which exists in the form of nitrites and nitrates?*

Because they are the result of the decay or decomposition of nitrogenous organic matter. As a rule, the amount that occurs in unpolluted water is very small, and even in polluted waters it is small when expressed in figures. The ammonia can without difficulty be determined when present, even in minute quantity.

2208.—*What are the indications of nitrites?*

Nitrites, as a rule, indicate more recent, and therefore more dangerous pollution, than can be inferred from the presence of nitrates. They readily pass into nitrates.

2209.—*What should be the limit of nitrates in water?*

The nitrogen as nitrates should in no case exceed 1 grain per gallon (= 3·86 grains N_2O_5); 0·7 grain N (= 2·7 grains N_2O_5) per gallon is a safer limit.

2210.—*What are the chief sources of nitrates in water?*

Oxidation of animal matter; more rarely of vegetable nitrogenous matter. Occasionally nitrates are formed in deep wells of chalk as a result of deposit with animal matter of some kind.

2211.—*Are nitrates and nitrites in themselves harmful?*

Not unless in considerable quantities.

2212.—*If nitrates and nitrites are alone present, when would you condemn the water?*

When they are found in a water-source liable to contamination of excremental filth.

CHAPTER XXVI.

EXAMANATION OF WATER—*continued.*

MICROSCOPICAL EXAMINATION OF WATER.

2213.—*Of what value is the microscopical examination of water?*

Microscopic examination of water is a means of obtaining solid information as to the charactor of a water that has not received the attention it deserves. Vegetable tissues, spiral vessels, or animal tissues, as muscular and elastic fibres, epithelium cells, and minute organisms, may thus be identified, and the probable source of the pollution ascertained.

Living organisms of all kinds, animal and vegetable, are frequently met with. They indicate, of course, the presence of pabulum, but do not of themselves suffice to condemn a water. Bacteria, bacilli, vibriones (minute jointed rods), and micrococci (spherical bodies), single grouped or in chains, require, as LEX has shown, organic carbonaceous matter, nitrates which they mostly reduce to nitrites, a trace of phosphates and oxygen (others, however, flourish best where oxygen is deficient), as SCHLOSSING, MUNZ and WOLLNY have proved. No water is free from them, but KOCH finds that their number affords an approximate estimate of its impurity. And while some are connected with the ordinary processes of decomposition, others—we cannot distinguish which—may be the germs of specific diseases. In either case it is clear that their presence in large numbers is very undesirable.

The examination with the microscope can, however, alone give accurate information of the nature of the suspended matters. Very high powers (1000 or 1200 diameters) are necessary for a complete examination, though lower powers will give much valuable information.

[From the study of the minute organisms habitually and occasionally present in air, water, and soil, it may be expected that great advances in sanitary science will be made.]

2214.—*What is the relation of living organisms to water ?*

Living organisms of all sorts and description, both vegetable and animal, are frequently met with in water. Their very presence naturally indicates the existence of a suitable food, which food is chiefly organic. They do not of themselves, however, entitle us to absolutely condemn the water in which they are found, yet a water containing an abundance of life must be regarded as inferior and less desirable than one that is clear and comparatively free from living organisms. The microscopical examination, therefore, forms an important supplement to the physical and chemical examination of water.* "Just as the mineral debris could afford us a clue to the nature of the strata of soil through which the water may pass, so the known *habitat* of certain organisms detected, should enable us, in a general way, to determine whether the water has been taken from a river, stream, lake, pond, well or other source. Indeed, if we were perfectly acquainted with the natural history of the forms occurring in a sample of water even in the absence of more definite information, we would have little difficulty in forming a conclusion to the source from whence the water was derived."*

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* From the AUTHOR's *Hygiene of Water and Water-Supplies.*

2215.—*What is meant by the Microzyme test for water ?*

The Microzyme test for water is one that was originally introduced to ascertain whether micro-organisms were present or not, but we now know that germs are present in all ordinary waters, and even in ice. The test consists in adding two or three drops of the water to be tested to 2 C.C. of *Pasteur's nutrient fluid*, the latter having been previously boiled in a sterilised test tube. If any bacteria, bacilli, etc., or their spores are present, the fluid in the test tube in a few days becomes milky owing to crowds of bacteria. This test is of little value to hygiene, although it tells us roughly the number of bacteria present, and enables those who follow this method of research to study the bacteorological and morphological characteristics of the germs. "The importance of the thorough acquaintance with the life history of the individual micro-organisms cannot be too strongly insisted upon. For example, by such means the spirillum of Asiatic cholera can be distinguished from other comma-shaped organisms, and inasmuch as its presence may be an indication of contamination with choleraic discharges, such water should be condemned for drinking purposes, even though we may not yet be in a position to affirm that the microbe is the cause of the disease."

As, however, even distilled water and the purest ice water may contain *bacteridia*, the test cannot be used as a positive indication of good or bad water, except in connection with others, and with due regard to temperature, which has a great effect. All it will show is, that the greater or less rapidity of appearance of opalescence will prove that microzymes are more or less abundant.

In any water which contains nitrogenous matter (of animal nature, at any rate), sugar, and a little phosphate, *fungi*, will soon appear, and the spores, no doubt, enter from the atmosphere. Spores, spore-cases, and delicate mycelium can be seen, and often *bacteridia* co-exist. If *fungi* are found in water, they indicate impurity, and such water should not be used if it can be avoided. The significance of the different forms is as yet obscure.

Both *spirillum* and *bacillus* can also be often detected in water. In addition to microzymes the water will always contain various allied *protesta*, which are usually termed *monads* zoogleæ which seem to have the same significance as *bacteridia*.

2216.—*Besides the Microzymic test mention another of importance for the detection of certain impurities in water.*

That of making cultivation experiments to ascertain the nature and number of the micro-organisms present. These are carried out by placing the microbes in suitable nutrient media in test tubes, or plates in which they can germinate and multiply.

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* A Guide to the Microscopical Examination of Drinking Water by J. MACDONALD, M.D., 2nd Ed.

2217.—*What is meant by the biological test?*

The *biological* test consists in the cultivation of any germs present in the water by bringing them into contact with sterilised nutrient media. This is a form of examination that has led to much information already, and has opened out a new field of research, and we are convinced that it is capable of yielding excellent results when carried out in its integrity.

2218.—*How is the biological examination of water conducted?*

As usually carried out the biological examination is conducted as follows:—A measured quantity of the water one C.C. or a fraction of a C.C. is mixed with a test tube full of liquefied sterilised nutrient gelatine which is then poured on a glass plate and placed under a bell-jar with suitable precaution to prevent the entrance of atmospheric spores. After a few days the germs or spores are found to have developed into recognisable colonies which may be counted and differentiated by their colour, their mode of growth, the liquefaction they produce in the gelatine, and other characteristics. Under microscope the colonies may be separated into the different varieties of bacteria moulds and fungi and each colony may subsequently be submitted to cultivation in test tubes of gelatine, blood serum, etc.

If liquefaction of the gelatine be produced round a colony, it does not necessarily show that the germs there are pathogenic. Under the microscope the colonies may be separated into the different varieties of bacteria, moulds, or fungi. To distinguish which are pathogenic, pure cultivations must be made of each colony separately, and animals inoculated therefrom (KLEIN).

2219.—*On the whole what conclusions may be arrived at in regard to the value of the biological test for water?*

Biological science has not as yet sufficiently advanced to enable us to put a definite interpretation on the result of such experiments; still we think that it may be asserted with regard to a given water, that its wholesomeness corresponds with the number of vegetable germs present. This is not always so however. Flowing water with abundance of specific germs may be less unwholesome than stagnant water containing fewer such microbes.

2220.—*When is the biological test specially valuable?*

When it is desired to confirm the results of chemical analysis and not because it is capable of throwing any further light on the dangerous or harmless qualities of a water. Under ordinary natural conditions waters found to be chemically pure are not capable of causing disease; and all waters with but very few exceptions which have caused disease, have been found by chemical examination to be polluted—often grossly polluted. Distilled water infinitesimally polluted with a few grains of enteric fever stool is not a water contaminated under ordinary natural conditions, and it would probably be passed as pure and wholesome by the biologist who had counted the number of bacteria in a cubic centimetre, as well as by the chemist who failed to find evidence of organic polllution sufficient to condemn it.

2221.—*What precautions are to be taken in collecting samples of water for biologial examination ?*

Too much caution cannot be exercised in collecting water samples for biological examination, for which purpose glass stoppered bottle are the best adapted. They ought to be *carefully* washed with distilled water, dried thoroughly and then sterilised by heating them in an air bath at a temperature of 180° C. for three or four hours.

2222.—*How may we sterilise water ?*

To completely sterilise water or any other fluid, it is necessary to boil it, or merely raise the fluid to a temperature of 212° F. without actual ebullition, for a short period (half an hour) on three or four successive days. In this way, the spores, which escape destruction by the first boiling, have time to develop into adult bacteria, which are destroyed by the next boiling, and so on, until all the successive crops are disposed of. Boiled water thus sterilised is flat and insipid, and should be aërated before being drunk.

2223.—*How do we proceed in making an ordinary microscopical examination of water ?*

We place a drop of the water on a cover glass, and allow it to evaporate (preferably under a bell glass). This may be examined at once, or passed through a flame three or four times, and then stained with one of various aniline pigments.

2224.—*What course is to be pursued in the microscopical examination of sediment when the amount of sedimentary matter is small ?*

When water is very turbid from an obviously impure source, it is easy enough to obtain a sufficient amount of sedimentary matter for microscopical examination, and a reliable estimate of the fitness of such water for drinking purposes may be thus readily formed. But it more frequently happens that the deposit, even after long standing is but slight, and when this is the case, we must have recourse to special means, by which the whole, or a large amount of the matters in suspension, may be concentrated, or collected together in a small compass. In the first place, a tall glass vessel should be filled with the water to be examined, and a circular disc of glass, attached to a long aluminium wire lowered to the bottom, when the whole arrangement lightly covered, must be set aside for twenty-four or forty-eight hours as the case may be.

At the end of the specified time, the water should be siphoned off with a piece of India-rubber tubing, so as to leave only a thin stratum of the liquid over the glass disc. This should now be carefully raised and laid upon blotting paper to dry its under-surface and remove the surplus moisture, when it may be at once transferred to the microscope, with a large piece of covering glass, so placed upon it as to exclude all air bubbles. An ordinary watch glass may in some cases be substituted for the disc alluded to, with advantage, as being less likely to permit the loss of sediment by overflow, which is certain to happen with a plain surface. The operator must be cautioned not to use iron wire, which rusts so rapidly that it will soon throw down a flocculent precipitate. Another good plan, which is perhaps the better of the two, is to siphon off the water until only a sufficient quantity remains to permit the sediment to be shaken up with it, and poured into a tall conical glass from which after standing again for a short time, portions may be taken up by means of a pepette, and placed on slides for examinations. If the subsidence is observed to be complete it is rather an advantage to have a good body of water in the glass, or at least so much as will permit the pepette to be used with ease and facility. It may be observed here that it is very inconvenient to have too much fluid at a time on a slide. The covering glass will be unstable and liable to have its upper surface wetted, while the objects themselves will be tremulous, if they do not quite run out of the field. To obviate this, pepette, when taken out of the water, should be held in a vertical position for some little time, until the suspended matters gravitate to the bottom of the tube, when a well charged droplet might be placed on a number of separate slides and examined seriatim. This is, in fact, the only way in which a large sediment can be thoroughly inspected.

2225.—*Should the microscopic examination of samples of water be always carried out?*

The microscopic examination of the sediment ought always to be performed where possible, as it often affords important information when the chemical investigation fails. Thus, the presence of such objects as muscular fibre, wheaten starch cells, mucous epithelium, disintergrating masses of paper, etc., are sufficient alone to condemn water (especially if it be from a shallow well), even when the chemical constituents are within limits, as they are undoubted evidences of animal contamination, almost certainly sewage. In such cases the nitric acid is nearly always large in amount.

2226.—*What is the usual object of the microscopical examination of the sediment of water?*

The object of this examination, in a majority of cases, is to determine whether the water has been polluted with sewage or domestic refuse.

2227.—*What bodies are usually found in polluted water?*

Fibres of cotton, wool, or linen, starch cells, macerated paper, human hairs, yellow globular masses, and striped muscular fibres (undigested meat) with squamous epithelium cells, are all indicative of contamination of the water with human refuse, and most probably with sewage. Amongst these matters, and feeding on them, will probably be found living organisms of a low type, such as bacteria (micrococci, bacilli, and vibriones) amœbæ, and infusoria. These organisms are not in themselves dangerous, but they indicate the presence of matters—chiefly organic—upon which they feed, and amongst them may be those disease-producing organisms which so often find their way into sewage.

2228.—*What precaution should be taken in order to collect the sediment?*

The water should be allowed to stand for 12 to 24 hours.

If a sample of water intended for dietetic purposes be turbid, a tall cylinder may be filled with it and allowed to rest, and after the surpernatant liquid has been removed by a syphon, the residue may be examined microscopically for low forms of animal or vegetable life, and for evidence of organic pollution from town sewage or manufactories, such as cotton, linen, or woollen fibres, muscular tissue, etc.

2229.—*Are all vegetable germs in water harmful?*

By no means; some indeed exercise a purifying influence by feeding on, and bringing about a disintegration of, the organic impurities contained in the water. Certain forms of micro-organisms split up the nitrogenous (animal) matter and convert it into ammonia, nitrites, and later on nitrates.

Some germs are related to ordinary decomposition processes; whilst others, and we cannot distinguish which, may be the seeds of specific diseases. That certain forms of micro-organisms bring about specific diseases, such as enteric fever, cholera, etc., is now a generally recognised fact. These germs are the least readily determinable of all impurities, evading all chemical examination.

Water containing an abundance of life must be regarded as inferior and less desirable, than one that is clear or comparatively free from living forms.

2230.—*Describe the method of conducting plate cultivations.*

The follwing is recommended on good authority:—A shallow glass dish is placed on a tripod stand, filled with water, covered with a glass plate, and the level carefully adjusted by means of a spirit-level, which is then removed, and replaced by a piece of filter paper the size of the glass plates to be used, and then covered with a [illegible]s. The glass plates are put into an iron case and sterilised in a hot-air steriliser heated to 150° C. (302° F.) where they are kept for an hour or two. The water in the dish is now cooled by means of crushed ice; a sterilised plate is removed from the case by means of sterilised forceps, held between the finger and thumb by opposite edges, and rapidly transferred to the filter paper on the glass plate. The vessel containing sterised gelatine is warmed in a vessel of water heated to 30° C. (86° F.) inoculated with the sample by means of a sterilised pepette, and well mixed by shaking, avoiding the formation of air bubbles; the bell-glass is raised, and the gelatine is poured on to the plate, the plug being previously removed, and the gelatine is quickly spread over the plate by means of a sterilised glass rod to within half an inch of the border of the plate. The bell glass is replaced, and the gelatine allowed to set. When quite set, the plate is transferred to the damp chamber.

In two or three days the cultivation may be examined, and the colonies counted; and for this purpose a glass-plate ruled into square centimetres, arranged on a frame so that it may be placed over the plate containing the cultivation, may be requisite, so that the number of colonies beneath one square, and the number of liquefying colonies also, may be counted. Individual organisms may then be examined by means of cover-glass preparations, and by further inoculations of nutrient gelatine and other media.

Dr. DUPRE (Report of the Medical Officer, in 14th Report, 1884, p 304; 15th Report, 1885, p. 309; and 17th Report, 1887, p. 272, of the Local Government Board) has investigated the changes effected in the aëration of water by the life processes of particular micro-organisms under different conditions of temperature, light, and nutrient material; but all that can at present be said is, that some organisms cause the disappearance of oxygen under the influence of organic matter in the light, others only in the dark.

Professor W. R. SMITH, of King's College, in the preliminary report on the *Differentiation and Identification of Micro-organisms found in water-supplies*, (Report of the Medical Officer, 17th Report, 1887, p. 268) has also investigated the micro-organisms in the water supplied by two of the London Water Companies.

2231.—*What was the method adopted by* Prof. W. R. SMITH?

His method was to make gelatine plate cultivations at 20° C. (68°F.), and agar-agar plate cultures at 30°C. (86°F.) and with the organisms thus developed mice were inoculated; but in no case was any noteworthy result obtained. He did not detect any disease-producing organism, but colonies of microphytes of multifarious character such as *Bacillus fluorescens liquescens*, Staple *coccus flavus liquescens*, *Bacillus erythosporus*, and others whose identity with known organisms was not established. But, whatever method be adopted, the information afforded is at present of very limited value, for (1) all the organisms introduced into the culture medium may not be capable of propagation in this latter; and

(2) each colony may possibly be the produce of one or more individual organisms, but this is not likely; (3) accidental contamination of a water after collection may readily occur.

2232.—*What is* Dr. ANGUS SMITH'S *method for recognising that micro-organisms are present in water ?*

It consists in introducing, by means of a capillary sterilised pepette, drops of the fluid into gelatine or gelatine-broth in test tubes plugged with sterilised cotton-wool, and heated to 35°—40° C. (95°—104° F.). The tubes are then shaken so as to distribute the inoculated liquid through the gelatine, which is then allowed to cool and set. After a few days the colonies of organisms that liquefy gelatine may be recognised as clusters disseminated through the gelatine (which they liquefy). The size of the clusters, their appearance and groupings, are then noted. Dr. PERCY FRANKLAND ('Proceedings of Royal Society,' Vol. xxxvii, 1885, p. 379) and Dr. WARDEN, of Calcutta, ('Chemical News,' Vol. lii, 1885, pp. 52, 66, 73, 89 and 101) have published valuable methods of determining the relative numbers of micro-organisms present in waters, by means of plate cultivations. This may be done by adding a measured small quantity of the water to be examined to a definite quantity of liquefied sterilised nutrient gelatine, in a sterilised test tube. The mixture is well shaken and poured into a glass plate, placed beneath a bell-glass in a moist chamber and kept at a temperature of 70°—72° F. (21°—22·8 C.). After a few days the number of colonies, their shape, size, colour, and other characters, may be noted.

The water is allowed to stand for few hours, till most of the particulate matter has subsided, and then a little of the fluid and sediment is withdrawn by means of a long capillary pepette. Some of the fluid and sediment thus removed is used for microscopic examination whilst fresh; whilst another portion is prepared after the WEIGERT-KOCH method; by spreading out the fluid on a cover-glass in a thin layer, drying it, fixing by passing three times through a flame, staining with a suitable aniline dye, such as methyl-blue, magenta, or gentian-violet; washing successively with water, alcohol, and distilled water; drying, and then mounting the preparation in Canada balsam dissolved in benzene or xylol. Test tubes containing sterilised cultivation material, such as agar mixture, gelatine, or Pasteur's fluid, are also inoculated with the fluid in the pepette, by piercing the plug of cotton-wool with this. The test tubes are then placed in the incubator for a day or two, and then a portion is withdrawn by means of a capillary pepette, and used for microscopic examination in order to ascertain what kinds of organisms are present; for the unaided eye generally suffices after a day or two's incubation to ascertain whether organisms are present or not. New cultivations may also be made from the first cultivation. [This is a good method for determining the presence of micro-organisms in water, though less useful in determining their characters.]

2233.—*Into what two large classes may we divide vegetable organisms found in water?*

Into (1) algæ and diatoms, and (2) fungi. The former are present in nearly all running streams, and, therefore, cannot be held to contra-indicate the use of the water; indeed, they may assist in purifying and oxidising it. Fungi, on the other hand, requiring the presence of nitrogenous, carbonaceous, and phosphatic matter, are evidence of impurity. The so-called *sewage fungus* of HEISCH forms rapidly in water, to which sugar has been added if kept in a warm place. It is therefore not characteristic of sewage, but indicates an amount of decomposing organic matter enough to absolutely condemn any water. It presents the appearance of grape-like clusters of spherical transparent bodies, and in its growth it develops butyric acid, recognisable by its rancid odour. *The spores are derived from the air.*

2234.—*What are* KOCH'S *and* FRANKLAND'S *methods of cultivating micro-organisms?*

Dr. KOCH'S process consists in cultivating the lower forms of life, in a solid medium by means of which the growth of each colony is localised. The medium used by Dr. FRANKLAND in conducting this process is made as follows:—

Infuse one pound of finely cut meat in half a litre of cold water and strain.

Digest 150 grammes of gelatine in another half litre of cold water and mixing it with the meat extract, heat till the whole of the gelatine is dissolved, when add 1 gramme of sodium chloride and 10 grammes of solid peptone and mix.

Now carefully neutralise this liquid with carbonate of soda; clarify by beating it up with two or three eggs, boil, strain through cloth and filter through sterilised bibulous paper. Upon cooling it sets to a transparent jelly.

Before setting, 7 or 10 C.C. are poured into (each of) a number of *clean* sterilised test-tubes, which are afterwards *tightly* plugged with cotton-wool and again sterilised by steaming them for half an hour at a time for three or four consecutive days.

2235.—*What conclusions may be arrived at when we find abundance of the lower forms of life in water?*

It may be stated that the lowest organisms like bacteria when present in large numbers indicate that putrefactive changes are taking place, and generally that the presence of bacteria, amœbæ, and infusoria, must be regarded with great suspicion, because the polluting materials with which they are associated are more likely to be dangerous than the vegetable masses from ditches and ponds amongst which the higher organisms are usually found. The bacteria of unwholesome water liquefy gelatine cultivation-media more readily than those from wholesome waters.

2236.—*Are these methods generally employed?*

They are not, because no means are known which enable the microscopist and analyst to discriminate between pathogenic, zymogenic, and presumably inert bacteria, by mere inspection.

2237.—*What are the most important micro-organisms met with in water?*

Of the *vegetable* organisms *fungi* are the most important, requiring the microscope for their detection. The chief forms of fungi met with in water as far as public health is concerned are, bacteria, bacilla, vibrios (minute chained rods), micrococci (spherical particles singly or in clusters), all of which require as food organic carbonaceous matter, nitrates which they reduce to nitrites, a trace of phosphates, and usually oxygen. Many organisms, however, flourish better in the absence of oxygen. No natural water is free from these vegetable germs.

The number of micro-organisms in different kinds of water varies considerably, but on the whole corresponds with, and gives an approximate estimate as to the degree of impurity. Some important investigations carried out by Dr. PERCY FRANKLAND pointed out that the unpurified water of the Thames contained about 1,000 micro-organisms to the drop, but after passing through the filters of the water companies, the same water contained on an average only 20 micro-organisms. The actual number of germs in a water is of importance also from the fact that in their multiplication they generate poisonous bodies called *ptomaines*.

Ordinary putrefactive bacteria, vibriones, and cocci may not in themselves be harmful, yet their presence in any numbers in water points to the probability of the existence of dangerous organic matter, this organic matter serving as a pabulum upon which such micro-organisms feed and multiply. They are the most pernicious of all impurities in water, for some forms of these microphytes produce disease in man. It need scarcely be said that they are invisible, some requiring the highest powers of the microscope for their detection.*

2238.—*What opinion may be given as to the number of vegetable microbes permissible in water?*

KOCH is of opinion that a normal water is one which contains less than 300 germs in each cubic centimetre. FLUGGE and KROSKAWER would not permit more than 50 to 150 germs at the most, and the Swiss Society of Analytical Chemists fixed the latter figure as their maximum. A. PFEIFFER condemns a water when the germs reach 1,000 per cubic centimetre (FERD. FISCHR, 'Zeitsch f. Angew Chemie,' 1889, No. 18). These conclusions are widely diverse, and no account is taken of the *kinds of germ* met with. It is obvious that until we have some means of distinguishing between innocent, and perhaps beneficent germs, and those which are disease-producing, the mere counting of germs is a valueless operation.

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* From the AUTHOR's *Hygiene of Water and Water-Supplies*.

A water that has an offensive smell, or exhibits many moving organisms, or on cultivation shows a number of colonies of diverse species, is absolutely unfit for use.

The identification of the spores of *fungi*, and even of the mycelium as seen in water, is so extremely difficult that it would be at present rash to affirm that any fungoid elements are distinctive of fæcal matter. The butyric acid smell also is given off by so many impure waters that it could hardly be used as a test for fæces.

2239.—*Are micro-organisms usually met with in ordinary potable waters?*

Microbes are always present in natural waters, even the purest; but their number is greatest in impure water. Both moving and motionless organisms are found—micrococci, bacteria, bacilli, spirilla. Most of them multiply rapidly in water, especially if impure, at the ordinary temperature, and they are continually recruited by aerial microbes.* Hence the number is constantly changing, and affords only a very rough indication of the quality of the water. If a small measured volume, say 5 C.C., of the water is added to nutrient gelatine, and a plate cultivation made, the number of colonies can be counted. Little is known of the significance of most of the varieties met with, but the great majority are doubtless perfectly harmless. Some pathogenic microbes have been detected in natural waters; among them those alleged to be the causes of cholera, enteric fever, and malaria. The comma bacillus thrives for months in sewage, but soon perishes in pure water. The same is true of bacillus anthracis, but the spores retain their vitality even in distilled water. A bacillus, known as *Beggiatoa alba*, characterised by the presence of grains of sulphur in its substance, is found in marsh water and in sulphur springs. It grows freely in water containing sewage, and also in the effluents from certain manufactories, especially sugar factories and tan-yards. The dense flocculent greyish-white masses of Beggiatoa have been regarded as evidence of the presence of sewage. They reduce sulphates, and will grow in water in which sulphates abound, whether derived from sewage or not.

2240.—*Are the larger organisms of putrefaction dangerous?*

Evidence on this point is not very clear, although it tends to show that such organisms are rather beneficial than harmful, inasmuch as they consume or live on the smaller and more dangerous ones.

2241.—*Are putrefactive fungi in water harmful?*

At present there seems no reason to think that common (putrefactive) *bacteria* and *vibriones* are in themselves hurtful, but they indicate the existence of putrefactive organic matter, which is a danger. But there may be, and probably are, forms of *bacteria* which are more dangerous, and which may hereafter be distinctly differentiated by careful cultivation. For this purpose a sample of the water must be examined by mixing a small measured portion with gelatine (especially prepared) or other nutrient medium. This, when fluid, is poured over a glass plate, and set aside in a cultivating apparatus. In a day or two, colonies of minute organisms will show themselves. These can be counted by the microscope, and stated as so many per cubic centimetre. Note may also be taken of the characters of each, and whether or not they liquefy the medium. Separate pure cultivations can then be made.

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* A sample of water from a deep chalk well contained 7 microbes when fresh, 21 after standing for a day at 20° C., 495,000 after standing three days (FRANKLAND).

It may be stated that the lowest organisms like bacteria, when present in large numbers, indicate that putrefactive changes are taking place, and generally that the presence of bacteria, amœbæ, and infusoria, must be regarded with great suspicion, because the polluting materials with which they are associated are more likely to be dangerous than the vegetable masses from ditches and ponds, amongst which the higher organisms are usually found.

Pollution of water with vegetable matters may be recognised by the presence of vegetable cellular tissue, fungi and moulds, algæ, diatoms, desmids and confervæ. Amongst decaying vegetable matter will be found an abundance of microscopic living organisms, including bacteria, amœbæ, euglenæ, infusoria vorticellæ or water worms, rotifera or wheel animalcules, entomostraca, daphnia pulex (water flea), cyclops quadricornis, amphipoda, rhisopoda and tardigrada (water bears), the larvæ of the water gnat, and the pupa forms of other insects, besides many others.

2242.—*What is the relation of vegetable life fungi, algæ, etc., to water?*

Of the vegetable fungi met with in water, we have bacteria, bacilli, vibriones, (minute chained rods) micrococci (spherical particles, singly or in chains), all of which require as food organic carbonaceous matter, nitrates, (which they reduce to nitrites), a trace of phosphates and oxygen. Many micro-organisms, however, flourish better in the absence of oxygen. No natural water is free from these vegetable germs, and the number present gives an approximate estimate of its impurity (KOCH). It need scarcely be said that these bodies are invisible and therefore all the more dangerous.

Some germs are related to ordinary decomposition processes, whilst others, and we cannot distinguish which, may be the seeds of specific diseases.

The vegetable organisms which cause the most trouble and inconvenience are those which appear as greenish specks, or minute straight or curved threads, diffused through the water—visible enough if a large quantity of water be looked at, but perhaps almost escaping notice in the small quantity which would be taken up in a single glass. It is true that the individual plants are in some cases distinguishable by the naked eye; but their form and structure can be made out only by use of the microscope. If collected together as a scum, which often happens, especially on the windward shore of a pond, the scum is not coherent, is easily broken up, either by a wind setting in the opposite direction, by a shower of rain, or by artificial agitation. The appearance has been sometimes described as that of meal or of fine dust scattered through the water. The number of individuals is almost infinite; and under favourable conditions they increase with great rapidity.

While very many species of the minute algæ present this general appearance, the number of species which are known to increase to a great extent as to completely fill the waters of ponds of several acres in dimensions, and to cause sensible inconvenience, is comparatively small.

2243.—*What are the chief living organisms found in water?*

Rhizopoda, infusoria, hydrozoa, rotifera, scolecida, entomostraca, and insecta are found in water, together with fungi, algæ, diatomaceæ, and many other organisms For the most part these are believed to be harmless in themselves, though infusoria, (*e.g.*, paramæcium, vorticella,) and fungi indicate the presence of impurities. Among the parasites which are believed to be conveyed by water are certain tape-worms, the guinea-worm, Dochmius duodenalis, Bilharzia, and leeches. They may be found in the adult or embryonic form, or as ova.

2244.—*What parasites have been found to gain-entrance into the human being through drinking water?*

Anchylostoma (or selerostoma) duodenale; Ascaris lumbricoides, Bilharzia hæmotobia, Bothriocephalus latus, Distoma hepaticum, Dochmius (or strongylus) duodenalis, Filaria dracunculi, and Filaria sanguinis hominis.

2245.—*Of what parasites have the embryos or eggs been found in water?*

Tænia solium; Bothriocephalus latus; Ascaris lumbricoides (round worms); Oxyuris vermicularis (thread-worms); Filaria sanguinis hominis, the embryos of which are sucked from the blood by mosquitos and then transferred to water; Bilharzia hæmatobia; and Distoma hepaticum (liver fluke of sheep). The guinea-worm (Filaria dracunculus) is said to penetrate into the subcutaneous cellular tissue of the legs of bathers, whilst leeches may fix themselves in the pharynx and cause much hæmorrhage.

2246.—*What is the sewage-fungus? What are its peculiarities and habitat?*

The sewage-fungus (Beggiatoa alba) is found in waters containing an abnormal amount of sulphates derived either directly from sewage or from substances used in precipitating sewage, and also from manufacturing refuse and waste waters. The fungus form dense flocculent greyish-white masses attached to floating vegetation or to the banks of streams. Under the microscope it is seen to consist of an immense number of colourless threads containing bright strongly refractive globular particles of sulphur. The *threads branch dichotomously*.

[Under the microscope, sewer water contains various dead decaying matters, and in addition multitudes of *bacteria* and amœbiform bodies, as well as some ciliated infusoria, especially *paramecia. Fungi* (spores and mycelium) are seen, but there are few *diatoms* or *desmids*, and not many of the higher animals, such as *rotifera.*]

2247.—*What animal parasitic forms are found in water?*

Of the animal kingdom, the *rhizopoda* and *infusoria* are abundantly represented in pools, tanks, and rivers. They are themselves harmless, but point to an existing pabulum of organic matter in the water, which in many cases is in such quantity as to lead to serious contamination. *Hydrozoa* and *rotifera* are frequently present in good water. *Namatodæ* are often found in impure water. In this order are included the round and thread worms (which may inhabit the alimentary tract of human beings), the embryo of the guinea-worm, and the *filaria sanguinis hominis*, which plays such an important part in the production of elephantiasis and chyluria. These latter animal parasites are met with in the water of certain areas in which the affections created by them are endemic. The ciliated embryo of broad tape-worm passes through its first stage of development in the alimentary canals of certain fishes (eels and pike). *Leeches* are frequently met with in water. They are often dangerous from the great bleeding they may cause from the throat or stomach when they gain access to those organs. The absence of fish and molluscs in perennial rivers and tanks, denotes very bad water. Water fleas (*cypris*), *cyclops*, *daphnea*, etc., are found in apparently good water.

[Among higher animal forms the *hydrozoa*, *rotifera* and *entromostraca* occur so frequently, especially in spring time, in running brooks, that little weight can be attached to their presence. *Anguillulæ*, on the other hand, require so much organic impurity for their nourishment that they must be looked on with great suspicion; while leeches and the eggs or embryos of *filaria*, *ascarides*, flukes, and the various species of *scolecida*, and other entozoa are of the highest importance in themselves. The *Bothriocephalus* or tape-worm of Eastern Europe, has recently been discovered to be in its larval stage parasitic in the pike fish. Leeches have been known to cause dangerous hæmorrhages from the fauces and stomach; and in the tropics the guinea-worm, *Bilharsia*, etc., enter the human body from the water of tanks and like polluted sources.]

2248.—*May vegetable micro-organisms be found in ice?*

They may, and as a matter of fact they are frequently present in it. In connection with impure water should be mentioned impure ice. Ice is purer than the water from which it forms, but if cut from a foul pond or if manufactured from impure water it will itself be foul, and the vitality of some microspic organism is not destroyed by their being frozen, as is shown by the fact that samples from the centre of blocks of ice will inoculate sterilized infusions with the germs of putrefaction, precisely as the water of which the ice is composed would have done before it was frozen. Disease has been traced to impure ice, and it may be that it is more frequently due to this cause than has heretofore been supposed; at all events it is well to bear the possibility in mind.

2249.—*What is the significance of* ALGÆ, DIATOMS *and* DESMIDS *in water?*

Algæ, diatoms, and desmids are found in almost all running streams. and are also seen in many well waters. They cannot be held to indicate any great impurity; and to condemn water on account of their presence would be really to condemn all waters, even rain, in which minute algoid vesicles (*protococci*) are often found.

The forms of the various *confervæ* in water are very numerous; some being coloured green, whilst at other times they are quite colourless, round, isolated, or clustered vesicles. The immature forms may not be easy of identification. The *diatoms* are always readily recognised and identified. It may be stated generally that organisms of a grass-green colour, such as the green *algæ*, need not be objected to; but the bluish-green, such as the *oscillatorians*, *nostoc*, etc., are less desirable; not that they are probably directly injurious, but as indicating an impure water, and as being apt to give rise to an unpleasant ("pig-pen") odour. *Leptothrix ochræa*, which was at one time thought to be connected with a special disease poison, is really harmless, and is mostly found in waters containing a good deal of iron peroxide; such waters are usually singularly free from noxious organic matter.

There is no reason to believe that the presence of these minute algæ gives an unwholesome character to the water; and the inconvenience caused by their presence and decay is fortunately of short duration, being, as a rule, for only a few weeks of the year. They are not a sign of impurity, as they grow in ponds which are far removed from all sources of contamination; still a pond known to be subject to such growth would be, on this account, less desirable as a source of supply. There is no means known of preventing the growth, but by a properly-conducted filtration the water may be made much more acceptable to the eye and to the taste.

2250.—*What is the signifiance of rhizopoda in water?*

Rhizopoda, especially *amœbæ* and similar forms, may often be detected with the microscope. They appear to indicate, like *bacteridia*, the existence of putrefying substances, but this is not yet certain. They are not found in first-class waters.

2251.—*What is the significance of the various forms of* EUGLENÆ *in water?*

Euglenæ (of different species, such as *E. viridis*, *E. pyrum*, etc.) are found in many waters, especially of ponds and tanks. Ciliated, free, and rapidly moving *infusoria*, belonging to several kinds of common *protozoa*, such as *kolpoda*, *paramecium*, *coleps*, *stentor*, *kerona*, *stylonychia*, *oxytricha*, etc., are also found. The abundance of these bodies indicates, of course, that the water contains food for them, and this must be either vegetable or animal organic matter, but the mere presence of these *infusoria* will not show which it is. HASSALL noticed, however, in 1850, that the Thames water below Brentford, where it was mixed with sewage, swarmed with *paramecia*, while at Kew, where the water was freer from sewage matters, they had almost disappeared Subsequent observations have not, however, proved the relation between *paramecia* and animal matter in the water to be sufficiently constant to allow the former to be used as a test of the latter. Fixed or slow moving *infusoria*, as the *vorticellæ*, are also often seen in river waters.

In many waters the living objects in the above five classes comprise all that are likely to be seen, but in the other cases there are animals of a larger kind. [*Hydrozoa*, especially the fresh water *polyps*, are common in most still waters, and do not indicate anything hurtful.

2252.—*What forms of worms are found in water?*

Worms, or their eggs and embryos, belonging to the class *Scolecida*, may occur in water, and are of great importance. The eggs and joints of the tape-worm, the embryos of *Bothriocephali*, the eggs of the round and thread-worms, and perhaps the worms themselves, the guinea-worm, and other kinds of *filaria*; the eggs of *Dochmius duodenalis*, and other *distomata*, and the embryos of *Bilharzia*, have all been recognised in water, though it has not yet been shown that in all cases they can be thus introduced into the human body.

2253.—*What may be said with regard to the presence of infusoria in drinking water?*

As far as at present known, the existence of *infusoria* of different kinds is not hurtful, though they may indicate by their abundance the presence of organic impurity, which they are probably useful in getting rid of. The effect of microzymes, *algæ*, or

fungi, in drinking water is also a matter of which little or nothing is known, though it is very probable that future research may bring out something important in this direction, a line of research which is now only in the initial stage.*

The distinctly animal forms of rhizopods and infusoria are abundant in ponds, tanks, and some river waters; harmless in themselves, they prove the presence of organic matter, and some seem to point to serious degrees of pollution.

CHAPTER XXVII.

DISEASES PRODUCED BY CONSUMPTION OF IMPURE WATER.

2254.—*In general terms what may be said to be the relation between impure water and disease?*

Daily increasing evidence shows the intimate relation between impure water and disease. The rapid strides made in that branch of sanitary science that has for its object the investigation of disease-causes, place us in a position to state that the nature and quality of the water used by a community is a matter of vital significance. There is no factor that plays such an overwhelming part in the preservation of the public health as that of water-supply. Instinct taught this to the ancients, but prolonged and sad experience, together with developed science, have demonstrated it to us. It is really no exaggeration to affirm, that the unrestricted supply of water in a pure state is the first essential of decency, of comfort, and of public health. Without such a supply the poorer classes are bound to remain in a low stage of civilisation. Any great limitation to its use in towns, cities, and municipalities must keep the mass of the people in a condition of the most unwholesome filth and degradation. To the people of India the quality of their water-supply is perhaps more important than it is to any nation in existence, for they are the greatest water-drinkers known. It may in fact be considered their universal beverage. No greater improvement to a locality can be made than that of supplying each household, and each inhabitant, with wholesome water. Every occupied house of a town, municipality, or village should have, within a convenient distance, an available supply or wholesome water, sufficient for consumption and for domestic purposes. Such limitation of its use as we see in the bustees of Indian towns (and in many more advanced countries also) is necessarily associated with a condition of material and unwholesome filth.

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* HEHIR's *Hæmatozoon of Malaria.*

Town Commission in their invaluable reports. It was there shown that want of water leads to impurities of all kinds, the person and clothes are not washed, or are washed repeatedly in the same water, cooking water is used scantily, or more than once; habitations become dirty, streets are not cleaned, sewers become clogged, and in these various ways a want of water produces uncleanliness of the very air itself. The consequence either of a short supply of water for domestic purpose, or of difficulty in removing water which has been used, are very similar.

It is absolutely necessary that there should be a good supply of pure water in the neighbourhood of human habitations. Rivers, when not contaminated with sewage, are available for this purpose. In ancient Rome there were officers, *Curatores Alvii et Riparum* whose duty it was to take care of the banks of the Tiber and to regulate its channel. The channels of rivers, it should be remembered, are always liable to deterioration from physical causes in constant action.

2255.—*Short of producing pronounced disease may impure water act detrimentally to health ?*

Short of producing any active disease, the continuous use of foul water may bring about a general impairment of health, a lessened immunity from, and an increased liability to diseases of all kinds. All these maladies may owe, not only their origin, but also their continuation and propagation to infected water.

2256.—*What are the chief ways in which impure drinking water produces disease?*

(1) By its containing organic matter, vegetable or animal, living or dead, including in this, suspended parasites, their ova, or spores; and (2) by having dissolved in it excess of certain saline bodies, such as chlorides, carbonates, and sulphates of lime and magnesia, etc.

2257.—*Compare in respect of hygienic importance the several classes of impurities met with in water ?*

The *organic* impurities are by far the most important constituents of water, and they are the most powerful in producing disease. The *saline* bodies, when in excess, are not without their injurious effects, but when found they are more or less constant and unvarying, can be determined with accuracy, and the diseases they bring about can be readily and with certainty connected with them. Dead organic matter may give rise to diarrhœa, dysentery, malarial fevers, etc., but living organic matter in the form of specific micro-organisms may bring about specific diseases, such as cholera and enteric

2258.—*Is there any connection between impure water and epidemic diseases?*

There is a marked connection between certain epidemic diseases and impure water, so close indeed is this connection, that one is almost inclined to hazard the statement that such diseases can scarcely spread widely in a community, without its influence. It is a safe thing to assume that any severe outbreak of bowel-complaints in a community should call the attention of the sanitary authorities to the condition of the water-supply.

The experience in English towns has been reproduced in India. A remarkable instance is the case of the town of Burdwan, which carried out works for the supply of water for domestic purposes which were opened in December 1884. Previous to the construction of these works, the town was notoriously unhealthy, with a death-rate of 42 per thousand, which has now been reduced to 20 per thousand. In the town of Calcutta the death-rate now varies between 25 and 26 per thousand, although much remains to be done to perfect the present system of water-supply and drainage, which is rapidly approaching completion. The death-rate in the suburbs of Calcutta, in which water-supply and sewage works are about to be commenced, is now between 44 and 69 per thousand. The cholera death-rate has been reduced from an annual average of 4,056 to 1·492. The deaths from fever have been reduced in the following proportions :—

Periods of three years.	Total deaths from fever.
1877—1879	16,033
1880—1882	11,180
1883—1885	10,891
1886—1888	9,873

A similar experience has followed the introduction of a pure water-supply into the Residency Bazars, Hyderabad, and into part of Cudderghaut (a large and important suburb of the City of Hyderabad).

In all localities and under all heads of disease a steady improvement has followed the introduction of drainage and water works.

One thing is certain, wherever the use of unwholesome water has been supplanted by a purer supply, there cholera had considerably decreased.

2259.—*Is it easy to prove the relation of cause and effect between say certain constituents of impure water and diseases?*

It is not. Indeed, it is one of the most difficult matters to satisfactorily prove the sanitary effect of certain impurities contained in water, that is, to show the connection between the results of an analysis, and the pathological effects produced by the use of that water. This arises from our knowledge of the subject being less definite than is desired. Thus, the good or bad effect of moderately hard waters containing chalk is an open question; and although waters containing sewage, metals, living organisms, animal refuse, or salts, in excess, are decidedly objectionable, waters having traces of them may be used with impunity. It is, however, generally recognized that water can be considered good and potable when it is fresh, clear, without odour; when its savour is very weak; when it is especially neither distasteful, salt, or sweetish; when it contains little of extraneous matters; when it is sufficiently aerated; when it dissolves soap without forming clots; and when it cooks vegetables well.

2260.—*What are the hygienic considerations connected with water rendered impure by vegetable matter?*

Vegetable matter may be present in water, which is characterised by its brownish tint, the dissolved impurities sometimes do not exceed two grains per gallon. In the absence of a purer supply, a water of this description cannot be pronounced objectionable, provided that it is not stored in leaden cisterns and that the supply is constant. If stored in open air ponds or reservoirs it is improved by oxidation and light; and it is further improved by filtration through gravel and sand.

Water which contains a considerable amount of vegetable matter partly in suspension and partly in solution, is decidedly unwholesome.

It has been known to produce violent outbreaks of diarrhœa, and since the days of Hippocrates downward, it has been popularly acknowledged to be productive of ague, and other malarious ailments. In India there are several special instances on record in which ague has been much lessened in small communities by using well, instead of surface water, and there are good grounds for believing that apart from the influences attaching to improved drainage, the great decline of this disease throughout many parts of England where it formerly prevailed, is in some measure due to the use of purer water (PARKES).

It has been frequently stated that the readily oxidisable organic matters in water are the most dangerous. This opinion has probably arisen from the idea that a substance in rapid chemical change is more likely to excite some corresponding and hurtful action in the body; and it may be true, but there is no existing evidence which can be trusted on the point. There is, on the other hand, some evidence that animal matters forming fatty acids give rise to salts which, though not oxidising into nitrous and nitric acid, are as hurtful as the more oxidisable substances.

With regard to the origin of certain diseases said to be due to these fungi, it is quite possible that it is only when a water containing these germs is undergoing progressive deterioration, and exposed to certain conditions of weather capable of bringing about the multiplication of the germs, that these diseases arise.

2261.—*For water to produce specific disease what is necessary?*

That it be contaminated with the *maleries morbi*, germ, or specific poison of that disease, which is usually one of the fungi.

The injurious action of water contaminated by the specific poisons of disease is said by many to be unlimited both as to time and space—that once a water receives even a small specific contamination, it is ever afterwards dangerous, no matter how long or far it may flow or percolate. This is a very sweeping statement, and is contradicted by the fact of the proved wholesomeness of many waters that have been specifically contaminated. Indeed, were such an extreme view as this to be true, we in India should for ever be in danger of falling victims to fatal disease, for almost all rivers and wells are so contaminated.*

There is happily another proposition established by experience—that the causes which produce high mortalities are within the control of local authorities, and by substituting pure water for dirty or suspicious water, and by the prompt removal of filth, an abnormal death-rate may be considerably reduced and made to approximate to normal proportions. It is because this fact has been so thoroughly established, that the law gives large powers to the Municipal Boards to summarily deal with private rights and interests, in cases affecting the public health.

2262.—*Show the effect of a pure water-supply upon communities by special examples?*

Name of town.	Population.	Expenditure on water-supply.	Death-rate per thousand.	
			Before introduction of public water-works.	After introduction of public water-works.
		£		
Chester ...	39,569	74,816	30	23·3
Gildersome ...	4,000	2,000	27	16·
Hull ...	149,000	215,000	31	16·
Manchester ..	1,000,000	2,850,000	33	24·7

AUTHOR'S *Hygiene of Water and Water-*

2263.—*Give a table showing that the introduction of a pure water-supply decreases the death-rate of a town?*

That an impure and insufficient water-supply is coincident with a high death-rate is shown in the following table:—

Name of Town.	Population.	Water-supply, gallons per head.	Death-rate per 1,000.	REMARKS.
Christiana ...	122,036	39·7	18·44	Public water-works.
London ...	4,000,000	31·25	20·40	
Baltimore ...	408,520	54·00	21·90	
Boston ..	400,000	73·30	22·00	
Philadelphia ...	1,000,000	54·15	22·30	
Genoa ...	137,037	24·50	22·57	
Rangoon ..	134,176	28·00	22·92	
Stuttgart ...	110,000	26·40	23·50	
Rotterdam ..	162,139	22·45	23·50	
The Hague ...	130,000	17·60	23·60	
Chicago ...	560,693	102·50	23·60	
Trieste ...	146,357	4·4	30·00	
Lahore ...	128,000	10·00	31·91	Wells.
St. Petersburg ..	929,093	21·30	35·20	Polluted river.
Cairo ...	450,000	...	37·00	Do.
Madrid ...	397,816	3·3	38·30	
Seville ...	132,798	7·26	39·32	Partly river.
Delhi ..	173,393	...	47·86	Wells.
Ahmedabad ...	124,767	...	49·07	Polluted.
Pekin ...	500,000	..	50·00	Subsoil water.
Veramgam ...	18,990	...	61·24	

2264.—*What was* Prof. **PARKES**' *opinion as to the advisability of supplying communities with an abundant supply of pure and wholesome water?*

"That although it is not at present possible to asign to every impurity in water its exact share in the production of disease, or to prove the precise influence on the public health of water which is not extremely impure, it appears certain that the health of the community always improves when an abundant and pure water-supply is given; and, apart from this actual evidence, we are entitled to conclude from other considerations, that abundant and good water is a primary sanitary necessity."

With regard to the necessity of an abundance of pure wholesome water, Sir JOHN SIMON remarks*:—

"The doctrine in general terms, that a vast influence is exercised over the health of communities by the quality of the water-supply which they consume, is one which, as far back in literature as any reference to such questions could be expected to exist, may be seen to have universal medical consent in its favour, and during long ages of history the common instincts of mankind were even surer and stronger than undeveloped science. Of the many invaluable additions and improvements which medical knowledge has received during the last quarter of a century, scarcely any can, in my opinion, be compared for practical importance to the discoveries which have given scientific exactitudes to parts of the above stated general doctrine, and have enabled us definitely to connect the epidemic spread of bowel infections in this country (England) with the existence of certain faults of water-supply. Not only is it now certain that the faulty public water-supply of a town may be the essential cause of the most terrible epidemic outbreaks of cholera, typhoid fever, dysentery and other allied disorders, but even doubts are widely entertained whether these diseases or some of them can possibly attain general prevalence in a town, except where the faulty water-supply develops them."

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* *Health Reports*, edited by the late Dr. EDWARD E. SEATON.

"Water should be distributed not only to every house, but to every floor in a house. If this is not done, if labour is scarce in the houses of poor people, the water is used several times; it becomes a question of labour and trouble *versus* cleanliness and health, and the latter too often give way. Means must also be devised for the speedy removal of dirty water from houses for the same reasons. In fact, houses let out in lodgings should be looked upon, not as single houses, but as a collection of dwellings, as they really are.

2265.—*Is extensive underground filtration effective in removing disease causes?*

The epidemic of enteric fever in Lausenne in Switzerland, where the specifically infected water which caused the outbreak, had passed underground through the earth for a distance of half a mile, shows that filtration, which was found at the time sufficient to prevent the passage of finely ground flour previously mixed with the water, was not capable of destroying or removing the specific disease poison.

We know of a case where the current of the underground water striking around the cesspools of a house, on its way to the well used for the water-supply of this house, gave rise to a serious outbreak of typhoid fever, showing the necessity of either doing away with the cesspool-system in this particular case, or of adopting a different position for such cesspool.

[The Rivers Pollution Prevention Act, 1876, provides that no rivers or streams shall be polluted through the admission of crude sewage, even from the existing sewers. The question then arises, how are we to deal with the sewage of towns, villages, and country mansions in a manner so as to be inoffensive? Numberless plans have been suggested for dealing with this question.]

2266.—*What are the pathological indications of impure water-supply?*

1. Diarrhœa	Arising from contamination by decomposing organic matter or specific germs.
2. Dysentery	
3. Dyspepsia	
4. Enteric (typhoid) fever	
5. Cholera morbus	
6. Scarlet fever	
7. Diphtheria	
8. Malarial diseases (ague, remittent fever, enlarged spleen and liver, anæmia)	
9. Furunculus	
10. Anthrax	
11. Entozoa	From the presence of parasitic ova.
12. Bronchocele (goitre)	From excess of lime and magnesia salts.
13. Calculi.	
14. Sallowness of skin	From presence of lead in injurious proportions.
15. Colic	
16. Disorders of sensation	
17. Amaurosis	
18. Tremors	
19. Paralysis	
20. Copper, zinc, arsenic, and mercury-poisoning	

2267.—*What are the chief diseases arising from impure water?*

Bowel complaints—cholera, dysentery, and diarrhœa; malaria fevers and the diseases connected with malaria—ague, remittent fever, enlarged spleen, anæmia or bloodlessness, and liver diseases; typhoid, enteric or bowel fever; dyspepsia or indigestion; urinary calculi, goitre, external and internal animal parasitic diseases, as guinea-worm and round-worms.

2268.—*State briefly the relations existing between certain diseases and impure water?*

Diseases due to impure water, are—*Diarrhœa*, due probably to the presence of organic matter, chiefly of animal origin. Suspended fine mica scales have also been accredited with the production of this disease.

Dyspepsia, or more properly certain gastric symptoms to which the popular term dyspepsia is applied, are said to be caused by the use of bad water.

Dysentery.—Several epidemics of this disease have been traced to the use of impure water, especially when impregnated with sewage.

Ague and other malarious fevers.

Miasmatic contagious disease.—Typhoid fever and cholera have been clearly traced to the use of impure water, and it is always advisable to examine the condition of water at the commencement of a sudden outbreak of either of these diseases.

2269.—*For practical purposes what are the two chief classes of vegetable micro-organisms?*

(1). Some germs which are related to ordinary decomposition processes; and (2), connected with the production of certain specific diseases. That certain forms of micro-organisms bring about specific diseases, such as enteric fever, cholera, &c., is now a generally recognised fact. These germs are the least readily determinable of all impurities, evading all chemical examination.

At present there seems no reason to think that common (putrefactive) *bacteria* and *vibriones* are in themselves hurtful, but they indicate the existence of putrefactive organic matter, which is a danger. But there may be, and probably are, forms of *bacteria* which are more dangerous, and which may hereafter be distinctly differentiated by careful cultivation.

The admixture of even a small quantity of these infected discharges with a large volume of drinking water is sufficient for the propagation of those diseases amongst persons using such water.

2270.—*What effect is likely to be produced by organic matters?*

The oxygen decreased, and the carbonic acid increased; the amount of nitrogen is usually constant.

2271.—*Which is the more dangerous, fresh or putrefying sewage?*

The latter is decidedly the more dangerous. Putrefying sewage apart from containing the specific poison of disease, is probably the most dangerous impurity water can contain.

2272.—*What is the relation of diarrhœa to drinking water?*

That diarrhœa may result from the drinking of impure water, no sanitarian will doubt. The diarrhœa thus produced may be of a varied character, and be due to a variety of causes.

1. Sulphuretted hydrogen in a water may cause diarrhœa. In the Mexican War of 1861-62, a form of diarrhœa was produced by the drinking of water abounding in alkaline sulphides (PONCET). Medicinal sulphuretted waters (*e.g.*, those of Harrogate) are well known purgatives. Other fœtid gases in water (*e.g.*, sewer gases) may produce a similar result.

Fœtid gases.—Water containing much hydrogen sulphide will give rise to diarrhœa, especially if organic matter be also present. In the Mexican War (1861-62), the French troops suffered at Orizaba from a peculiar dyspepsia and diarrhœa, attended with immense disengagement of gas and enormous eructations after meals. The eructed gas had a strong smell of hydrogen sulphide. This was traced to the use of water from sulphurous and alkaline springs; even the best waters of Orizaba contained organic matter and ammonia in some quantity. The experiments of Professor WEBER have shown what marked effects are produced by the injection of hydrogen sulphide in solution in water into the blood; is it possible that water containing animal organic matter may occasionally form SH_2 after absorption into the blood, and that the posionous effect of some water may be owing to this? The symptoms of poisoning by water contaminated by sewage are sometimes very like those noted by WEBER in his experiments, *viz.*, diarrhœa and even choleraic symptoms (lowering of temperature), and irritation of the lungs, spine, liver, and kidneys.

The absorption of sewer gases, as when the overflow-pipe of a cistern opens into the sewers, will cause diarrhœa. This seems perfectly proved by the case recorded by Dr. GREENHOW in Mr. SIMON's second report (PARKES).

2. Suspended matters, animal (fœcal), vegetable, and mineral, may cause diarrhœa, some of these—*e.g.*, clay, mica, etc.—may act as simple mechanical irritants, whilst suspended animal and vegetable substances may act specifically upon the intestinal tract.

3. *Dissolved nitrogenous organic matter.*—An excess of this if of animal origin, may provoke diarrhœa. That derived from cemeteries is generally supposed to do this in a marked manner. The writer's experience is, however, that such dissolved matters are not generally more prone to do this than other animal substances.

The animal organic matter derived from graveyards appears to be especially hurtful; here also ammonium and calcium nitrites and nitrates may be present.

Impure water plays an important part also in producing *diarrhœa.* This is especially the case if the impurity arises from decomposing animal and vegetable matter. But sometimes dissolved or undissolved mineral matter also creates the disease, and many observations made on this latter point show that the diarrhœa so prevalent on the hills is due to suspended mica scales, and finely divided particles of silica.

Outbreaks of diarrhœa are also very liable to appear when well water becomes contaminated with the animal organic matter derived either from graveyard or other sources,

4. *Dissolved mineral matters.*—These, even when of the most simple and innocuous character, when in excess may have a purgative effect, as is seen in the case of many purgative medicinal waters. Sulphate of magnesium and sulphate of calcium are most notable as producing this effect. The illness produced may be of a specific character, as in the case of contamination by lead or by chromium.

Dissolved mineral matters, if passing a certain point, produce diarrhœa. BOUDIN refers to an outbreak of diarrhœa at Oran, in Algiers, which was distinctly traced to bad water, and ceased on the cause being removed; the composition of the water is not explicitly given, but it contained lime, magnesia, and carbonate of soda. Sulphates of lime and magnesia also cause diarrhœa, following sometimes constipation. The selenitic well waters of Paris used to have this effect on strangers. PARENT-DU-CHATELET noticed the constant excess of patients furnished by the prison of St. Lazare, in consequence of diarrhœa, and he traced this to the water, which "contained a very large proportion of sulphate of lime and other purgative salts;" and he tells us that PINEL had noticed the same fact twenty years before in a particular section of the Salpêtriére. In some of the West Indian stations, the water drawn from the calcareous formation has been long abandoned, in consequence of the tendency to diarrhœa which it caused.

Calcium nitrate waters also produce diarrhœa. A case is on record, in which a well water was obliged to be disused, in consequence of its impregnation with butyrate of calcium (105 grains per gallon), which was derived from a trench filled with decomposing animal and vegetable matters (PARKES).

2273.—*What is the relation between suspended animal and especially fœcal matters and diarrhœa?*

They have produced diarrhœa in many cases, such water always contains dissolved organic matters to which the effect may be partly owing.

In cases in which the water is largely contaminated with suspended sewage, it is important to observe that the symptoms are often markedly choleraic (purging, vomiting, cramps and even some loss of heat). This point has been again noticed by OLDENKOP of Astrachan, who found marked cholera symptoms to be produced by the water of the Volga, which is impregnated with sewage. Seven cases in one house of violent gastro-intestinal derangement (vomiting, diarrhœa, colic and fever) produced by water contaminated by sewage, which had passed into the cistern are recorded by Dr. GIBLE. In the prison at Halle an outbreak of diarrhœa, was traced by Dr. DOLBEUCK to the contamination of water with putrid substances. In St. Petersburgh the water of the Neva which is rich in organic substances gives diarrhœa to strangers.

Suspended animal and vegetable substances, washed off the ground by heavy rain into shallow wells, have often produced diarrhœa, as at Prague in 1860.

2274.—*What relation has dissolved vegetable matter to diarrhœa?*

There is some evidence to show that this produces diarrhœa. WANKLYN cites the case of the Leek workhouse and also that of Biddulphmoor, in both of which vegetable matter in solution appeared to produce diarrhœa (PARKES).

Vegetable matters in water in solution or suspension may cause diarrhœa. Water drawn from peat is not objectionable; it should not be stored in lead cisterns, and should be filtered before it is used; it has been known to cause diarrhœa. Water from marshes should be avoided, it may cause diarrhœa.

2275.—*What is the relation between dissolved animal organic matter and diarrhœa?*

The opinion is very widely diffused that dissolved putrescent animal organic matter, to the amount of 4 to 14 parts per 100,000 may produce diarrhœa. This is possibly correct, but two points must be considered, 1st, that there are usually other impurities which aid the action of the organic matter, and, 2nd, that organic matter, even to the amount of 14 to 21 parts per 100,000 may exist without bad effects if it be perfectly dissolved. In the latter case, the water is, however, always clear and sparkling, never tainted or disagreeable. The frequent presence of other impurities renders it difficult to assign its exact influence to dissolved organic matters.

In the case of a well-ventilated court in Coventry, where diarrhœa was constantly present, the water contained 8·1 part per 100,000 of volatile and combustible matter, but then it contained also no less than 150 parts of fixed salts, which, as the water had a permanent hardness of 74 degrees (metrical scale) after boiling, must have contained considerable quantities of calcium and magnesium sulphates and chlorides. It also contained alkaline salts, nitrates and ammonia. The composition was therefore so complex, that it is difficult to assign to the organic matter its share in the effects. The animal matter derived from graveyards appeared to be especially hurtful, here also ammonia and calcium nitrates and nitrites may be present.*

2276.—*What is the relation of suspended vegetable substances to diarrhœa?*

In England and also in the late American Civil War, several instances have occurred of diarrhœa arising from the use of surface and ditch water, which ceased when wells were sunk; possibly there might be also animal contamination. It is not therefore quite certain that suspended vegetable matter was the *vera causa.*

2277.—*Is vegetable matter injurious?*

Yes, excess of it either in suspension or solution may cause diarrhœa.

2278.—*What is the relation between suspended mineral substances and diarrhœa?*

Clay or marl, as in the cases of the water of the Maas, the Mississippi, the Missouri, Rio Grande, Kansas, of the Ganges, and many other rivers—will at certain times of the year produce diarrhœa especially in persons unaccustomed to the water. The hill diarrhœa at Dharamsala and other hill stations in India, as Darjeeling, is produced apparently by suspended very fine scales of mica.

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* Parkes' *Practical Hygiene*, 7th, Ed.

2279.—*What is the relation of fœtid gases in water to diarrhœa?*

Fœtid gases.—Water containing much hydrogen sulphide will give rise to diarrhœa, especially if organic matter be also present.

The absorption of sewer gases, as when the overflow-pipe of a cistern opens into the sewers, will cause diarrhœa.

2280.—*What special agents in tank water has been known to give rise to disease?*

Excess of mineral matters, particles of mica and silica, with organic salts, which may give and has given rise to, diarrhœa, dysentery, and even ulceration of bowels, dyspepsia, etc., in those not accustomed to it.

2281.—*What rules did the late* Prof. PARKES *lay down in regard to the relation between impure water and disease?*

1. An endemic of diarrhœa, *in a community*, is almost always owing either to impure air, impure water, or bad food. If it affects a number of persons suddenly, it is probably owing to one of the two last causes: and if it extends over many families, almost certainly to water. But as the cause of impurity may be transient, it is not easy to find experimental proof.

2. Diarrhœa or dysentery, constantly affecting a community, or returning periodically at certain times of the year, is far more likely to be produced by bad water than by any other cause.

3. A very sudden and localised outbreak of either enteric fever or cholera is almost certainly owing to introduction of the poison by water.

4. The same fact holds good in cases of malarious fever, and, especially if the cases are very grave, a possible introduction by water should be carefully inquired into.

5. The introduction of the ova of certain entozoa by means of water is proved in some cases—is probable in others.

2282.—*What is the relation of certain forms of impurities in water to dyspepsia?*

Symptoms which may be referred to the convenient term dyspepsia, and which consist in some loss of appetite, vague uneasiness or actual pain at the epigastrium, and slight nausea and constipation, with occasional diarrhœa, are caused by water containing a large quantity of calcium sulphate and chloride, and the magnesian salts. Dr. SUTHERLAND found the hard water of the red sandstone rocks, which was formerly much used in Liverpool, to have a decided effect in producing constipation, lessening the secretions, and causing visceral obstructions; and in Glasgow, the substitution of soft for hard water lessened, according to Dr. LEECH, the prevalence of dyspeptic complaints. It is a well-known fact that grooms object to give hard water to their horses, on the ground, that it makes the coat staring and rough—a result which has been attributed to some derangement to digestion. The exact amount which will produce these symptoms has not been determined, but water containing more than 8 grains of each substance individually or collectively appears to be injurious to many persons. This would correspond to about 10 degrees of permanent hardness. A much less degree than this will affect some persons. In a well water at Chatham, which was found to disagree with so many persons that no one would use the water, the main ingredients were 19 grains of carbonate of lime, 11 grains of calcium sulphate, and 13 grains of sodium chloride per gallon. The total solids were 50 grains per gallon. In another case of the same kind, the total solids were 58 grains per gallon, the calcium carbonate was 22, the calcium sulphate 11, and the sodium chloride 14 grains per gallon.

Iron, in quantities sufficient to give a slight chalybeate taste, often produces slight dyspepsia, constipation, headache, and general malaise. Custom sometimes partly removes these effects.

2283.—*What is the relation of marsh water to malarial diseases?*

Marsh water has, however, from early times been considered unwholesome and a provocative of disease. HIPPOCRATES refers to the popular notion in his time, that those who drink the water of marshes get hard and enlarged spleens. The inhabitants of marshy tracts of country are pretty generally agreed that these waters may produce fevers.

2284.—*May water cause malarial diseases?*

It may. Ague, and other malarial diseases, although mostly caused by breathing malarial air, is sometimes due to water. That marsh water creates enlarged spleen and ague was known to the ancients.

Apropos of this origin of ague, we might relate the case of a European officer who recently arrived in India and went on a shooting excursion. On the first day he forgot to convey his bottle of water, and was obliged to drink the impure water of a swamp or *jheel*. The afternoon he did so he suffered from a severe attack of ague, and the following morning had symptoms of an attack of acute dysentery.

That the drinking of marsh water is a cause of intermittents, has been so generally adopted that the possibility of the introduction of the cause by means of water, as well as of air, was overlooked. Still, it has been a very general belief among the inhabitants of marshy countries that the water could produce fever. HENRY MARSHALL says that the Singhalese attribute fevers to impure water "especially if elephants or buffaloes have been washing in it," and it is to be presumed that he referred to periodical fevers. On making some inquiries of the inhabitants of the highly malarious plains of Troy during the Crimean War, Dr. Parkes found the villagers universally stated, that those who drank marsh water had fever at all times of the year, while those who drank pure water only got ague during the late summer and autumnal months. The same belief is prevalent in the South of India and in Western Candeish, Canara, Balaghat, and Mysore, and in the deadly Wynaad district, it is stated by Mr. Billington, of the Madras Civil Service, that it is notorious that the water produces fever and affections of the spleen. The essay by this gentleman gives, indeed, some extremely strong evidence on this point. He refers to villages placed under the same conditions as to marsh air, but in some of which fevers are prevalent, in others not; the only difference is, that the latter are supplied with pure water, the former with marsh or nullah water full of vegetable debris. In one village there were two sources of supply—a tank fed by surface and marsh water, and a spring; those only who drank the tank water got the fever. In a village (Tulliwaree) no one used to escape the fever; Mr. Billington dug a well, the fever disappeared, and, during fourteen years had not returned.

Another village (Tambatz) was also "notoriously unhealthy"; a well was dug, and the inhabitants became healthy. Nothing can well be stronger than the positive and negative evidence brought forward in this paper. Dr. Moore also noted his opinion of malarious diseases being thus produced, and M. Commaelle has since stated, that in Marseilles paroxysmal fevers formerly unknown have made their appearance since the supply to the city has been taken from the canal of Marseilles. In reference also to this point, Dr. Townsend, the Sanitary Commissioner for the Central Provinces in India, mentions that the natives have a current opinion that the use of river and tank water in the rainy season (when the water always contains much vegetable matter) will almost certainly produce fever, (*i.e.*, ague), and he believes there are many circumstances supporting this view. In this way the prevalence of ague in dry elevated spots is often, he thinks, to be explained. He mentions also, that the people who use the water of streams draining forest lands and rice fields, suffer more severely from fever (ague) than the inhabitants of the open plain drawing their water from a soil on which wheat grows. In the former case there is far more vegetable matter in the water. The Upper Godavery tract is said to be the most aguish in the province, yet there is not an acre of marshy ground, the people use the water of the Godavery, which drains more dense forest land than any river in India.

In the "Lavells" (of south-west of France the water from the extensive sandy plain contain much vegetable matter, obtained from the vegetable deposit, which binds together the siliceous particles of the subsoil. It has a marshy smell, and, according to Faure, produces intermittents and visceral engorgements. Dr. Blane, in his papers on Abyssinia, mentions that on the march from

Massowah to the Highlands, Mr. PRIDEAUX and himself, who drank water only in the form of tea or coffee, entirely escaped fever, while the others who were less careful suffered, and, as Dr. BLANE believes, from the water.

The same facts have been noticed in England. Many years ago Mr. BLOMER, of Bedford, mentioned a case in which the ague of a village had been much lessened by digging wells and he refers to an instance in which in the parish of Houghton, almost the only family which escaped ague at one time was that of a farmer who used well water, while all the other persons drank ditch water. At Shurness the use of the ditch water which is highly impure with vegetable debris has been also considered to be one of the chief causes of the extraordinary insalubrity.

At Versailles a sudden attack of ague in a regiment of cavalry was traced to the use of surface water, taken from a marshy district.

The case of the "Argo" recorded by BOUDIN, is an extremely strong one. In 1834, 800 soldiers in good health embarked in three vessels to pass from Bona in Algiers to Marseilles. They all arrived at Marseilles the same day. In two vessels there were 680 men without a single sick man. In the third vessel, the "Argo," there had been 120 men; thirteen died during the short passage (time not given), and of the 107 survivors no less than 98 were disembarked with all forms of paludal fevers, and as BOWDIN himself saw the men, there was no doubt of the diagnosis. The crew of the "Argo" had not a single man.

All the soldiers had been exposed to the same influence of atmosphere before embarkation. The crew and the soldiers of the "Argo" were exposed to the same atmospheric condition during the voyages, the influence of air seems therefore excluded. There is no notice of the food, but the production of malarious fever from food has never been suggested. The water was however different, in the two healthy ships the water was good. The soldiers on board the "Argo" had been supplied with water from a marsh, which had a disagreeable taste and odour: the crew of the "Argo" used pure water. The evidence seems here as nearly complete as could be wished.

One every important circumstance is the rapidity of development of the malarious disease and its fatality when introduced in water. It is the same thing as in the case of diarrhœa and dysentery. Either the fever-making cause must be in larger quantity in water, or, what is equally probable, must be more readily taken up into the circulation and carried to the spleen than when the cause enters by the lungs.

In opposition, however, to all these statements must be placed a remark of FINKE'S, that in Hungary and Holland, marsh water is daily taken without injury. But in Hungary, Dr. GROSZ states that to avoid the injurious effects of the marsh water, it is customary to mix Condy with it "a custom which favors hypertrophies of the internal organs." Professor COLIN, of the Val de Grace, who is so well known for his researches on intermittent fever, is also inclined to question the production of paroxysmal fevers by marsh water. He cites numerous cases in Algiers and Italy, where impure marsh water gave rise to indigestion, diarrhœa, and dysentery, but in no case to intermittent fever, and in all his observations he has never met with an instance of such an origin of ague. He therefore denies this power, and in reference to the celebrated case of the "Argo" without venturing to contest it, he yet views it with suspicion, and the question whether BOUDIN has given the exact results. An instructive case, however, is recorded by Brigade-Surgeon FAUGHT. The artillery quartered at Tilbury Fort (in the Gravesend district) have generally suffered more or less from ague, whilst the people at the railway station, and the coast guard and their families in the ship lying just outside the fort never suffered from malarious-poisoning. The troops have been supplied with drinking water from the underground tanks which receive rain water from the roof of the barracks, whilst the other persons above mentioned draw their drinking water from a spring near the railway station. From December 1873 to July 1874 the troops were supplied from the same source on account of the barrack tanks being out of order. At stations where care is taken with the water-supply and especially where suspended matter is prevented as much as possible from getting into the water, the disease is slight. The introduction of a pure water-supply in inland stations in India is invariably connected with improved general health, but specially with decrease in malarial diseases.

2285.—*Give an instance of excessive annual rainfall causing malarial disease.*

A remarkable instance of excessive rainfall, causing an outbreak of malarial disease, occurred at Kurrachee, in Scinde, in 1869. The average annual rainfall in Scinde in 11 years (1856-66) was only 6·75 inches; and the greatest rainfall in that time was 13·9 inches (1863). In 1867 the rainfall was 2·73, in 1868 it was 3·36 inches, while in 1869 it reached the unprecedented amount of 28·45 inches; of which 13·18 fell in July and 8·39 inches in September. April, May, October, November, and December were rainless. The 1st Batt., 21st Regiment, had the following attacks of paroxysmal fever per 1,000 of strength:—In April, none; in May, 9; in June, 39; in July, 30; in August, 93; in September, 105; in October, 189; in November, 1,004; and in December, 644. In December the regiment was embarked for Madras, as it had "thoroughly lost heart." The disease was not fatal, as the death-rate for the year, from all causes, was only 25·7 per 1,000. At Kurrachee, as the rainfall is usually so small, the ground dries fast, and is then non-malarious. The ground is flat, and there is no subsoil drainage. In 1866, when there was heavy rainfall (13·75 inches), there was also a development of malarial disease, which was continued in 1867.*

Impure water is credited with being a fertile source of dysentery. The connection of this disease with the use of impure water has been well recognised for many decades.

CHEVERS in India, CHAMPOUILLON in France, and MCGRIGOR in the Spanish Peninsula, have each observed outbreaks of dysentery from the same now well-recognised cause. Generally, it may be stated that those forms of water-pollution—gaseous, soluble, and suspended matters—which produce diarrhœa may, under other circumstances, produce dysentery.

2286.—*What is the relation of cholera to the consumption of impure water?*

In lower Bengal, and in some of the larger towns and cities of India, cholera is endemic. It has occasional epidemic outbreaks in those places, but an entire cessation of the disease rarely occurs, or occurs only at certain seasons of the year. When the circumstances under which this dreadful disease takes place are present, and it has once made it appearance, it may spread to an indefinite extent. Water is one of the chief means by which cholera is spread. There are doubtless other agencies through which it may be diffused, such as impure air, foul clothes, etc., yet water, in most outbreaks, plays an important part in this respect. This is shown from the great decrease of the disease in Calcutta and Madras since a supply of pure water to those cities has been introduced. The chief water-supply of Calcutta was formerly from open tanks and the Hoogly river. The tanks were subjected to contamination in various ways. Into the river Hoogly the night soil of the city was allowed to flow, and dead bodies (many probably the corpses of deceased cholera patients) were thrown. The matter was inquired into and a new and improved water-supply was started, with the result that the number of cholera cases has decreased by one-half.

A few instances will show how impure water brings about cholera. Several hundred emigrants were on board a ship in the Indian Ocean. All the people used the drinking water that was supplied in Calcutta from the public hydrants, one of the coolies got cholera. The issue of Calcutta water was prohibited, and pure water, distilled from the sea, used instead. The distilling apparatus got out of order, and Calcutta water had to be used once more. The day this was done several fresh cases of cholera occurred. The only conclusion to be arrived at is that the water in the public hydrants was contaminated. But how is the water rendered impure in such a way as to give rise to cholera? It is generally believed that the poison of cholera exists in the excreta of patients suffering from the disease, and that water becomes in some way or other affected by these excreta. In many outbreaks, the soiling of the water by the excrement of cholera patients has been proved. A notable instance occurred in London in 1854. A little girl was attacked with cholera in the streets. Her evacuations were passed near a pump, the material finding its way to the water in the pipes below. In 24 hours, 145 persons suffered from the disease, and all those who suffered obtained their water from this pump. Further, at this time, a woman living some miles away, got the disease, and it was proved that this person, preferring the water from that particular hydrant, used it with the result recorded.

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* PARKES' *Practical Hygiene*, 7th Ed.

Few of the earlier investigations of cholera appear to have imagined that the specific poison might find entrance by the means of drinking water. There is an intimation of the kind in a remark by Dr. MULLER, and JAMESON alludes to the effect of impure water, but in a cursory way.

In 1849 the late Dr. SNOW in investigating some circumscribed outbreaks of cholera in Horsleydown, Wandsworth, and other places came to the conclusion that, in these instances, the disease arose from cholera evacuations finding their way into the drinking water. Judging from the light of subsequent experience, it now seems extremely probable that this was the case, and to Dr. SNOW must certainly be attributed the very great merit of discovering this most important fact. At first, certainly, the evidence was defective, but gradually fresh instances were collected, and in 1854 occurred the celebrated instance of the Broad Street Pump in London, which was investigated by a committee, whose report drawn up by Mr. JOHN MARSHALL, of University College, with great logical power, contains the most convincing evidence that, in that instance, at any rate, the poison of cholera found its way into the body through drinking water.

In 1855 Dr. SNOW published a second edition of his book, giving an account of all the cases hitherto known, and adding some evidence also as to the introduction in this way of other specific poisons.

Cholera is endemic—that is, it is always present to a greater or less extent—in Lower Bengal. It has there occasional epidemic outbreaks; but an entire cessation of the disease occurs only for a few months of the year. In several of the large towns and municipalities of India, it is also endemic, as in Calcutta, Bombay, Benares, Hyderabad and its suburbs, etc. When the conditions favourable to the propagation of this disease are present, and it has once made its appearance, it is liable to disseminate to an unlimited extent. Water is one of the chief means by which the disease is spread. There are doubtless other agencies by which it is diffused, such as air specifically contaminated, foul clothes, food, etc., yet water in most outbreaks plays an important part in this respect. This is shown from the decrease of the disease in all those areas where it was endemic on the establishment of a permanent supply of pure water—Calcutta and Madras for example.

The water-supply of Calcutta was formerly from open tanks and wells, and the Hoogly river. The tanks and wells were constantly subjected to various forms of pollution. Into the Hoogly the night-soil of the city was allowed to flow; and dead bodies (many probably the corpses of deceased cholera cases) were thrown. A new and improved water-supply was started some years ago with the happy result of a decrease in the general death-rate, and in particular of mortality from cholera. A similar statement holds good of Madras. Sir JOHN SIMON writes: "The discharges from the bowels of infected patients, escaping into wells and other water-courses, are indubitably a powerful means of contagion. Water so polluted has been at the bottom of many widespread and decimating epidemics." The whole of the literature of hygiene or preventive medicine is pervaded with thoroughly authenticated instances to prove this.

2287.—*Give any special instances of this kind that have come under your own observation.*

A few instances that have come under our own observation will serve to show how impure water brings about cholera:—

(1) When in charge of several hundred Indian emigrants on board a sailing vessel in the Indian Ocean, cholera broke out. All the people had up to this time used the drinking water put on board at Calcutta. The issue of this water was at once prohibited and distilled sea-water used instead. But the distilling apparatus got out of order, and we were obliged to return to the Calcutta water. The day we resumed its use several fresh cases of cholera took place. The only conclusion one can come to is that the Calcutta water was polluted in such a manner as to be capable of creating the disease.

(2) In investigating the cause of an outbreak of cholera amongst some *wadders* (daily labourers) near the village of Khairatabad (Hyderabad, Deccan), we discovered that the people attacked procured their water from a putrid pool close at hand. As each person lived separately, there is reason to consider that they were all affected by a common cause, and that cause we believe to be the poison contained in the foul water they drank; for, on stopping the use of the water, the disease disappeared from the locality.

(3) On another occasion, on the confines of the village of Khairatabad, we saw a woman washing the soiled clothes of her deceased husband (who had succumbed to cholera) in a small tank, from which several people were at the time drawing water for drinking purposes. The tank was, of course, at once closed, but the truth of the astonishing ignorance of the lowest classes of the people remains, and causes us to wonder that a disseminating epidemic has not visited us long ere this. Such facts as these should arouse the energies of every intelligent being to do his utmost to disperse a knowledge of the rudiments of sanitation throughout the length and breadth of this Empire. Cholera prevailed in this village for several days after this.

(4) Last year while seeking the cause of cases of cholera in Begum Bazaar, a suburb of Hyderabad, we entered several huts where patients were suffering from the disease. In one hut we found a man prostrated with cholera. He had passed his stools on the ground around, and had vomited on several parts of the floor, soiling also his cooking utensils and a *lotah*. On making enquiries we found that his wife had just drunk water out of this very lotah. The man recovered, but his unfortunate wife died of the disease, the victim of appalling ignorance.

[A direct proof of the contagiousness of the excreta of cholera patients is given in the following often-quoted cases. A small quantity of a cholera stool was mixed by accident in water contained in an earthenware vessel. The chatty was exposed to the sun for many hours. Next morning nineteen persons each swallowed a small quantity of this water. Within 35 hours, five of them were seized with cholera. Instances of outbreaks of cholera from water specifically contaminated by the excreta of cholera patients abound in medical and hygienic literature; we would add but the few foregoing to the long list already in existence. As we have said before, cholera arises in other ways than through polluted water, but there is a consensus of opinion amongst authorities on the subject, to the effect that impure water is the main factor that brings about its extension. We need not enter into this relation, except in stating that it is now beyond doubt that some of the most appalling outbreaks of cholera have been definitely linked with impure water-supply. In the year 1879 five millions of people died in India, 3½ millions from fever, and 265,000 from cholera. In the Chudderghant Municipality in the year 1888 there occurred 736 cases. About ⅖ths of these proved fatal. Against the polluted water theory of cholera production is the fact, that most of those who drink such water escape cholera. But the same may be said with regard to enteric fever, and to us this exemption indicates that two factors are necessary to the production of cholera—(1) a specific poison (be it a bacillus, or *ptomaine* or animal alkaloid, or organic poison), and (2) a good nidus or breeding ground in the alimentary tract of the individual consuming the water, giving rise to a susceptibility to the disease.]

2288.—*What two diseases are said to be specially related to the level of the subsoil water?*

Cholera and enteric fever.

2289.—*Have any observers confirmed* PETTENKOFER'S *theory?*

Yes, in the report of D. D. CUNNINGHAM and the late R. T. LEWIS it was shown that cholera at Calcutta in 1873-4 followed the curve of the ground water-level inversely that is exactly in accordance with PETTENKOFER'S views.

The existence of specific poisons, capable of producing cholera and typhoid fever, is attested by evidence so abundant and strong as to be practically irresistible. These poisons are contained in the discharges from the bowels of persons suffering from these diseases.

Cholera and enteric fever, diarrhœa and dysentery, we know to be sometimes spread by means of infected or polluted water.

Drinking-water has been found to be so closely associated with several outbreaks of cholera in England and India, as to leave no room for doubt that it is an occasional factor of the highest importance.

2290.—*Give the details of what is known as the Broad Street Pump outbreak of cholera ?*

The district, in which a formidable outbreak of cholera occurred, had a population in 1851 of 42,272, and was not a low-class district. During August, 1854, cholera was prevalent in the locality but not to a serious extent, but on September 1st the disease broke out with fearful violence, and continued till the morning of the 5th, when it began to abate. One of the chief features of this memorable outbreak was its suddenness, and the large number of individuals simultaneously attacked in different parts of the district. The total number of deaths from cholera recorded in September in this limited area was 609, or14·2 per 1000 of the population. This district contained a public pump—the Broad Street pump; and this pump was the centre of the infected district, for starting thence, a person walking at a moderate pace in any direction would have gone beyond the limits of the infected area within three minutes. A special examination showed that the water of the well was contaminated by filtration from a cesspool during the time of the cholera outbreak. Though the water of the well was grossly impure, it was in great repute throughout the neighbourhood for drinking purposes, and was much liked, being cool, sparkling with carbon dioxide gas, and keeping well, in consequence of the large quantity of saline matter it contained. But on exposure to the air for a few hours it lost its freshness, and became offensive in a few days. Dr. SNOW was able to show that not only was the outbreak, properly so called, principally confined to the area about the pump, but that 61 out of 73 persons who died during the first two days had been accustomed to drink the pump-water; that in the workhouse, where the well-water was not used, the deaths from cholera were only one-tenth of the ratio prevalent in the neighbourhood; that no less than 9 per cent. of the people in a factory where the water was drunk daily died; and that 70 men employed in a brewery in Broad Street, and who never drank the water, all escaped cholera. Investigation of numerous individual cases entirely confirmed the conclusion that the Broad Street pump water was mainly instrumental in propagating the outbreak of disease.

2291.—*Give the details of the* 1866 *outbreak connected with the East London Water Company supply ?*

Perhaps a still more striking experiment was made in the east of

London, in the cholera outbreak of 1866, by the East London Water Company, which, in the language of the Rivers Pollution Commissioners ('Sixth Rep.,' p. 145) distributed 'unfiltered water excessively polluted with sewage, and which, in the opinion of Mr. NETTEN RADCLIFE, was specifically contaminated with the excrement of the first two patients who died in that year of cholera in the east districts of London.' Now the district of the East London Company supplied with water from this Old Ford reservoir, was the portion of their district which was the sole area of intense cholera in London in 1866. Again to quote Sir JOHN SIMON's words, 'The area of intense cholera in 1866 was almost exactly the area of this particular water-supply, nearly, if not absolutely, confined to it and scarcely, if at all, reaching beyond it' (*Ibid.*, p. 144).

[Water from water-courses, canals, ditches, and rivers is mostly very impure, and is liable to carry disease-causes. Thus the epidemic of cholera which visited the south of London in 1854, was caused by the distribution of impure Thames water, and that which visited the east of London in 1866, was produced by the distribution of contaminated water of the river Lea.]

2292.—*Give some specific instances in which cholera-rate has been reduced by the introduction of a pure water-supply.*

Calcutta Madras	Said to be reduced by cent. per cent.
Residency Bazars, Hyderabad	No outbreak since introduction of public water-supply in 1888.

2293.—*What are the general facts known in relation to the connection between impure water and cholera?*

According to the late Prof. PARKES there may be summed up as as follows :—

Local outbreaks, in which contamination of the drinking water was either proved or in which the evidence of the origin and succession of cases seemed to make it certain that the cause was in the drinking water. In England, Dr. SNOW and others have thus recorded cases occurring in 1849 and 1854 at Horsleydown, Broad Street, Wandsworth, West Ham, etc. In 1865, the important outbreak at Newcastle-on-Tyne, being investigated showed that all the circumstances pointed very strongly to the influence of the impure Tyne water. In 1865 occurred the remarkable and undoubted case of water-poisoning at Theydon Bois, recorded by Mr. Radcliffe, and in the following year the violent outbreak in the east of London was supposed to be connected with the circulation of impure water by the East London Water Works Company. Much discussion has taken place as to the real influence of the impure water, which it is admitted on all hands was used. Mr. RADCLIFFE and Dr. FARR collected the evidence in favour of the opinion that the sudden outburst was really owing to this water; while Dr. LETHEBY and some tohers expressed doubts on this point, chiefly on account of the difficulty of reconciling with the hypothesis certain exceptional cases both of immunity and of attack. The evidence in favour of the water being the cause appears extremely strong, and far greater difficulty arises if that view is not received than is caused by the exceptional cases referred to, of which we may not know all the particulars.

In 1849 the late Dr SNOW, in investigating some circumscribed outbreaks of cholera in Horsleydown, Wandsworth, and other places. came to the conclusion that, in these instances, the disease arose from cholera evacuations finding their way into the drinking water. Judging from the light of subsequent experience, it now seems extremely probable that this was the case, and to Dr. SNOW must certainly be attributed the very great merit of discovering this most important fact. At first, certainly, the evidence was defective, but gradually fresh instances were collected, and in 1854 occurred the celebrated instance of the Broad Street pump in London, which was investigated by a committee, whose report, drawn up by Mr. JOHN MARSHALL, of University College, with great logical power, contains the most convincing evidence that, in that instance at any rate, the poison of cholera found its way into the body through drinking water.

In 1855 Dr. SNOW published a second edition of his book, giving accounts of all the cases hitherto known, and adding some evidence also as to the introduction in this way of other specific poisons.

In Germany cholera water-poisoning has not only been less noticed, but the great authority of PETTENKOFER is against its occurrence. At Munich, PETTENKOFER could find no evidence whatever in favour of the spread by water, nor does he consider that any further evidence was furnished by the epidemics in Germany in 1873-4. Even HIRSCH, who was favourable to the water theory, expresses himself with considerable caution; and GUNTPER, in his careful work on Cholera in Saxony, asserts that no influence whatever was exerted by drinking water. No evidence could be obtained either in Baden or in villages near Vienna. And as in all cases the observers were not only quite competent, but were fully cognizant of the opinions held in England, this negative evidence is of great weight. At the same time, it cannot be allowed to outweigh the English cases, and, moreover, even in Germany some positive evidence has been given.

Authorities are agreed that a well or other water-supply source poisoned with cholera excrement, or enteric stools, or containing an excessive amount of organic filth is injurious to health.

2294—*What is the relation between the subsoil water level and the occurrence of cholera and enteric fever?*

We find that the level of the subsoil water alters very much during the year. It is supposed by Prof. PETTENKOFER that epidemic outbreaks of both enteric fever and cholera are coincident with changes in the water level of the soil. This he considers especially the case in loose or gravelly soil, and when well water is which has been taken from wells sunk into such soil, which has been contaminated by human excrement. According to this authority low water under these conditions, or a rapid rise in the water line after being low, or any great or sudden change in the water level, is sure to be followed by an epidemic of enteric fever. It appears that a process of development of matters excreted from the human body is necessary, in order to secure the evil results arising from excrementitious pollution of water, and this development in part takes place in contact with the soil; or certain organic changes occur in the soil, which could only be secured by a change in the water level. The fluctuating water line simply acts mechanically in furthering the processes of nature. We are of opinion that without the fluctuation in the water level, excremental pollution appears to be inoperative in producing epidemic disease. In India, cholera produces the greatest mortality at a time coincident with the lowest levels of the subsoil water. A fluctuating water line alone, however, is not the cause of disease, as we can well understand; for subsoil water may fluctuate and produce the most healthful results by promoting an aëration and purification of the soil. Disease is the result of excremental pollution of the soil, favored by certain descriptions of soil and variation in the subsoil water level within that soil. Those who design systems of sewers or drains will do well to remember when water is met within the soil, that this water may become a destructive agent to health and life by reason of its contamination by leaky sewers, the evil effects of which may be carried to considerable distances. All subterranean water must be looked upon not as so much inert matter, but as always on the move ready to carry the influences of pollution in the directions of its flow. It has often been observed that on sloping ground disease due to excremental pollution occurs only on the lower side of a street, under the houses of which the underground current of water is poisoned by a leaky sewer, or other receptacle of fæcal matter, while the houses located above the sources of pollution are healthy.

2295.—*May enteric fever be caused by water?*

It may, and this is now a well recognised fact, enteric fever has in a vast number of outbreaks been shown to be due to the contamination of water by the excreta of patients suffering from the disease. This is so well recognised as to need no further insistance here.

2296.—*What is the relation of enteric fever to water pollution?*

There is a constantly increasing amount of evidence accumulating in proof of the polluted water origin of enteric fever, and in all probablility this is the most common cause of the disease.

Water is one of the most important agencies in the spread of enteric fever. While water polluted even with excremental filth has often been drunk for years by numbers of people with perfect impunity so far as the appearance of enteric fever is concerned, the slightest contamination with the excreta of a case of enteric fever has over and over again been found to result in widespread outbreaks of the disease, the incidence of which in such instances exactly follows the distribution of the water, and affects only those persons who drink it. The virulence of the water-borne poison is not dependent upon the organic matter in the water, but upon the specific pollution. Thus an outbreak of enteric fever at Redhill and Caterham in 1879 was traced by THORNE THORNE to pollution of one of the adits at the Caterham Waterworks by the excreta of a workman suffering from a mild attack of enteric fever, the organic impurity of the water, as shown by analysis, being extremely small. A sudden outbreak at Guildford in 1867 was found by BUCHANAN to be limited to houses supplied by certain mains, which, upon one occasion only, ten days before the outbreak, had contained water from a well into which sewers were leaking. Here the analysis clearly showed pollution by sewage.

2297.—*What is* Sir W. JENNER's *opinion with regard to the contaminated water origin of enteric fever?*

The spread of typhoid fever is, if possible, less disputable than the spread of cholera by the same means. Solitary cases, outbreaks confined to single houses, to small villages, and to parts of large towns, cases isolated, it seems from all sources of fallacy, and epidemics affecting the inhabitants of large though limited boundaries, have all united to support by their testimony the truth of the opinion that the admixture of a trace of fæcal matter, but especially the bowel excreta of typhoid fever, with the water supplied for drinking purposes, is the most efficient cause of the spread of the disease. In any given locality enteric fever is limited or otherwise, just in proportion as the dwellers of that locality derive their supply of drinking water from polluted sewers.

2298.—*Can you refer to any instances bearing upon this point?*

Yes; an outbreak is recorded at a place in which the water of the adjacent river was for years contaminated by ordinary sewage, but those using the water were not known to suffer in any way. A case of enteric fever was imported into the village with the result that the disease occurred in an epidemic form in those using the river water.

2. Dr. THORNE THORNE's well cases in which workmen defæcating near the well caused enteric fever. The cessation of the use of the well water was associated with a simultaneous disappearance of enteric fever in the community.

2299.—*What was the late* Dr. BUDD's *opinion upon this point?*

The late Dr. W. BUDD said, in a letter to the late Dr. PARKES,—"In the cases in which the poison is conveyed by water, infection seems to be much more certain; and I have reason to think that the period of incubation is materially shortened. An illustration of this seems to be furnished by the memorable outbreak which occurred at Cowbridge some years ago, and which presented this unexampled fact: that out of some 90 or 100 persons who went to a race ball at the principal inn there, more than one-third were within a short time laid up with fever. In this case there was satisfactory reason to think that the water was contaminated, though there was no chemical examination." [In the attack at Guildford, however, the incubative period was not shortened, as Dr. BUCHANAN calculates it at 11 days; neither was it shortened in that at Caterham.]

2300.—*What was* Dr. THORNE THORNE'S *opinion upon the Winterton outbreak?*

The epidemic prevalence of fever in Winterton is undoubtedly to be ascribed to the disgraceful state of the privies, cesspools, ashpits, and wells. With the exception of about six houses, where water closets have been constructed, all the cottages are provided with privies, which are generally built of brick, and have an aperture on the sides or back through which they can be cleaned out. This aperture I found open in almost all instances, and the result of this is that the contents of at least half the privies in the town run out into the gardens, soak into the earth, and penetrate in many instances into the wells besides producing the most offensive odour. In addition to this, many of the tenants either throw their refuse and slops, including urine, into the yards, outside their doors, or else they improvise a receptacle by digging in the ground close to the aperture in the privy wells. The fæcal matters pour into it, and they thus add to their previous list of nuisances that of an open cesspool. In some instances ashpits have been built, but these are uncovered, and since urine and the bowel discharges of the typhoid patients are thrown into them in addition to other refuses, they are but little better than open privies. All the sources of fæcal fermentation are situated as a rule, close to the house, and in some instances, within a few feet of the back doors, and just under the windows.

The wells are also in their immediate neighbourhood and many of the inhabitants informed me that their water was so bad that they had been compelled to discontinue drinking it. In one instance I found the space between two pigstyes entirely occupied by a well 3 feet in diameter. Fever is present in the house to which the well is attached, but since the occupants do not use it, the necessarily contaminated condition of the water cannot be considered to bear upon the disease. Giving the existence of typhoid fever in a town, it is hardly possible to conceive of conditions more favourable for its spread than those existing in Winterton.*

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* Local Govtvernment Reports, 1867.

2301.—*Will decomposing sewage in water produce enteric fever, or must the evacuations of an enteric patient pass into the water?*

This is the part of the larger question of the origin and propagation of specific poisons. It is certainly remarkable, that the range of cases recorded by SCHMITT, have uniformly the possibility of the passage of enteric stools disregarded. Everything is attributed to fæcal matters merely. A case recorded by Dr. DOWNES in which six cases of enteric fever resulted from the overflow of non-enteric sewage into a well supports this view. On the other hand in the cases recorded by ALLBUTT and WHLARB, contaminated water has been used for some time without producing enteric fever. Persons affected with enteric fever, then entering the place, their discharges passed into the drinking water and then an outbreak of enteric fever followed. An extremely strong case is given by BALLARD, where very polluted water has been used for years by the inhabitants of the village of Nunney without causing fever, when a person with enteric fever came from a distance to the village, and the excreta from this person were dashed into the stream supplying the village. Between June and October 1872, no less than 76 cases occurred out of a population of 832 persons. All those attacked drank the stream water habitually or occasionally. All who used filtered rain water escaped except one family who used the water of a well only 4 or 5 yards from the brook. The case seems quite clear first, that the water caused the disease, and secondly that though polluted with excrement for years no enteric fever appeared until an important case introduced the virus.

Positive evidence of this kind seems conclusive, and *we may now safely assume that the presence of enteric evacuations in the water is necessary Common fæcal matter may produce diarrhœa, which may perhaps be febrile, but for the production of enteric fever the specific agent must be present.* The opinion that the stools of enteric fever are the special carriers of the poison was first explicitly stated by CONSTATT and was also ably argued by W. BUDD.

2302.—*Give some particular instances in which specific contamination of water has produced enteric fever.*

In 1860 an outbreak of enteric fever occurred at the Convent of Sisters of Charity at Munich; 31 persons out of 120 were attacked between 15th September and the 14th of October with severe illness, and 14 of these cases were true enteric; 4 died. The cause was traced to wells impregnated with much organic matter (and among other things enteric dejections) and containing nitrates and lime. On the cessation of the use of this water the fever ceased.

2. The propagation of enteric fever in Bedford would certainly appear from Sir J SIMON's report to have been partly through the medium of water.

3, In 1862 a very sudden and severe outbreak of enteric fever in a barrack at Munich was traced to water impregnated with fæcal matter—on ceasing to use the water the disease disappeared.

3. In 1866 enteric fever broke out in a girl's school at Bishopstoke near Southampton and was traced unequivocally to the bursting of a sewer pipe into the well. The water was disagreeable both to smell and taste. Seventeen or 18 persons were affected out of 26 or 28.

5. Several very striking instances are recorded in Sir J. SIMON's report by Drs. SEATON, BUCHANAN and THORNE, and in some of these analysis of the water were made which showed it to be impure and to contain organic sewage or its derivatives.

6. Dr. DERENZY, the Sanitary Commissioner of the Punjab, has also published a remarkable paper on the extinction of enteric fever in Millbank prison, and showed from the statistics of many years, that the fever has entirely disappeared since the use of Thames water was given up, the disappearance was coincident with the change in the water-supply.

7. A destructive outbreak took place at Caterham and Redhill during 1878. This was investigated by Dr. THORNE THORNE, who traced it to the contamination of the water-supply by the stools of a workman suffering from mild enteric fever, who was employed in the Company's wells. The disease was confined to those who consumed the water and ceased after the wells were pumped out and cleansed. The inmates of the Lunatic Asylum and the detachment of troops at Caterham barracks used the water from the Asylum well and did not suffer.

2303.—*Two questions arise in connection with this subject, what are they ?*

That enteric fever undoubtedlys preads by (1) water and (2) through the air.

2304.—*What is the proportion of cases disseminated by air ?*

No reliable answer can yet be given to this question.

2305.—*Is the specific contamination of enteric fever production held universally ?*

No. This view is not shared by some Army Medical Officers, for in tropical climates it is often impossible to connect an outbreak of typhoid with the contagion of a pre-existing case.

That water may be the medium of propagating enteric fever thus seems to be proved by sufficient evidence ; and it has been admitted by men who have paid special attention to this subject, as JENNER, W. BUDD, and SIMON.

The deficiency of water leading to insufficient cleansing of sewers has a great effect on the spread of enteric fever and of choleraic diarrhœa ; and cases have been known in which outbreaks of the latter disease have been arrested by a heavy fall of rain.

In several of the cases mentioned above, the proof of specific pollution was incomplete, and many authorities have held that sewage-polluted water may acquire the property of causing enteric fever in those who drink it, without the access of enteric excreta. In country districts, where the movements and identity of every person coming into the locality are easily traced, it has often been found impossible to obtain evidence of specific pollution of water which was nevertheless instrumental in spreading enteric fever. On the other hand, it is clear that something beyond simple excremental pollution is necessary to account for the sudden acquisition of morbific properties in a water which has long been polluted; and moreover, attacks of enteric fever may be so mild as to escape recognition, nor is it safe to disregard the possibility that the specific poison may gain access in ways as yet unsuspected. Upon the whole it is perhaps most reasonable to withhold judgment upon this point, and to affirm only that sewage-polluted water may convey enteric fever without the addition of the excreta of *known* previons cases of the disease.

2306.—*State some of the important facts connected with the hygienic relations of enteric fever.*

This endemic fever kills some five or six thousand people annually in England and Wales out of a population of twenty-six millions, or 0·2 per 1,000.

The poison of typhoid indubitably exists in the bowel evacuations of those suffering from the desease, and hence is very frequently introduced into drinking-water, which, as is now well known, thus becomes a chief, but by no means the sole agent in the distribution of typhoid.

Moreover, it is now pretty generally accepted that the germ of typhoid is a bacillous (Bacillus typhosus, E. Corth), or rod-shaped Schizomycete.

It is stated that inoculation experiments made with this bacillus have been successful (Renkel u. Simmonds' 'Die Ætiol. bed, des Typhus bacillus'). But long before this discovery was announced the connection between typhoid and water-supply had been one of the best established conclusions of scientific medicine; and the discovery of the active bacillus of typhoid seemed from a publichealth point of view merely to support the definite conclusions arrived at by statistical and individual inquiries into the causation of the disease.

The proofs of this assertion lie elsewhere. In 1854 typhoid fever, then the scourage of Millbank Prison, which drew its water from the polluted Thames, was practically extinguished by the cessation of the old supply and the adoption of a water-supply from the deep artesian well in Trafalgar Square ('Lancet,' 1872, i. p. 787).

2307.—*Does the subsoil filter out diseased germs from water passing through it to wells?*

In all probability it does not.

The epidemic of enteric fever at Lansenne in Switzerland where the specifically infected water which caused the outbreak had passed underground through the earth for a distance of half a mile shows that filtration which was found at the time sufficient to prevent the passage on finely ground flour previously mixed with the water was not capable of destroying or removing the specific disease poison.

2308.—*Has impure water any relation to the production of yellow fever?*

It has, but that relation is still unknown, BOUDIN quotes a case from ROCHARD in which a French frigate (in 1778) took in water at San Jago, where yellow fever prevailed. Some days afterwards yellow fever broke out with such violence that two-thirds of the crew were attacked. " And the proof that the only cause was the water," says ROCHARD, " was that the persons living with the captain had with them jars filled with water from Europe, and all escaped." BOUDIN very properly observes that this evidence is very defective ; but yet we must remember how completely the propagation of marsh and enteric fevers, and of cholera by water, has been overlooked, and how exactly this sudden and extensive attack resembles the case of the " Argo."

The Barrack Commissioners have also directed attention to the fact of the great impurity of the water at Gibraltar at the time of the yellow fever epidemic ; a difficulty which still remains to be dealt with in the event of the introduction of any epidemic disease.

As, like dysentery, typhoid fever, and cholera, the alimentary mucous membrane is primarily affected in yellow fever, there is an *priori* probability that the cause is swallowed also in this case and that it may possibly enter with the drinking water. But no good evidence has been yet brought forward.

2309.—*May diphtheria arise from drinking water?*

Diphtheria is not usually propagated through the medium of drinking water, but cases favouring such a view have been recorded.

2310.—*Is there any truth in the assertion that urinary calculi may arise from water?*

Urinary calculi were at one time supposed to arise from the use of hard water, but this view is now generally abandoned from want of any definite proof.

2311.—*What is the relation between calculi and certain impurities in water?*

It has long been a popular opinion that drinking lime waters gives rise to calculi (calcium phosphate and oxalate). Several medical writers have held the same opinion, and have adduced individual instances of calculi (phosphatic ?) being apparently caused by hard waters, and cured by the use of soft and distilled water. On a large scale, statistical evidence is apparently wanting. The excess of cases of calculi in Norwich and Norfolk generally is not, in Dr. RICHARD-

SON's opinion attributable to the water. Dr. J. MURRAY, of Newcastle, has given some evidence to show a connection between the lime waters and calculi, especially phosphatic, but it does not appear to be more convincing than that previously adduced.

At Canton stone is common, while at Amoy, Shanghai, Ningpo, and other places, it is not met with. The cause of the difference is not known, but it is not calcium carbonate in the water, as the Chinese always drink boiled water.

2312.—*What effects may arise from excess of mineral salts?*

Dyspepsia, diarrhœa or constipation, goitre etc., the effect depending upon the nature of the salt present.

Goitre, a swelling of the thyroid gland in the neck, is often associated with free use of drinking water from magnesian limestone formations. In some parts of Yorkshire, Derbyshire (hence the name "Derbyshire neck"), Hampshire, and Sussex, it still prevails, though much less commonly than formerly. In Switzerland cretinism, a congenital form of idiocy, frequently occurs in the same districts as goitre, and is apparently etiologically connected with similar conditions The exact origin of goitre is still uncertain. In many magnesian limestone districts it is unknown, while in some districts where this formation is absent, cases of goitre have occasionally occurred. The latest view is that sulphide of iron is the cause of goitre, and it is said that this is always present in magnesian limestone districts. Others hold that a miasmatic poison in the water is necessary for the causation of goitre, in addition to the metallic salts. Some believe that an organic poison of an unknown kind must be associated with the magnesian limestone to produce the disease. The view that the disease is due to iron pyrites and other salts of iron and copper often found in limestone regions is growing in favour; while others consider that the concurrent agency of some organic material is necessary. "Goitre appears to have been developed, under the use of certain drinking waters, in as few as eight or ten days. Urinary calculi are common in Norfolk and other chalk districts where the water is hard; but the dependence of the calculi upon the hardness of the water is far from being established. A good drinking water should not exceed 4 degrees of permanent, or 20 of total hardness. It is estimated that each degree of hardness involves a waste of upwards of a pound of soap for every 1,000 gallons used in washing."*

[There is however a general belief that goitre and glandular swellings, as well as the prevalence of urinary calculi in certain districts, are associated in some way with the use of hard waters. Notwithstanding the fact that goitre appears to be due, in many instances to the water used for drinking, the impurities in the water which favour hypertrophy of the thyroid gland in some districts, are not those found in the water of other goitrous districts.]

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*WHITELEGGE's *Hygiene and Public Health*, p.88.

2313.—*Does the magnesian limestone theory hold good in all regions where goitre is prevalent?*

No: for in many places analyses of the water gave complete absence of magnesia, such as Aheims, Auvergne, Bertrand, etc.

2314.—*Is the lime theory always true?*

It is not; in some cases no lime has been found in the water.

2315.—*What are the circumstances connected with the occurrence of goitre in certain parts of India?*

In certain parts of Oudh, such as Ghurwal, Kamaon, etc., about 33 per cent. of the inhabitants are said to suffer from goitre; yet in the water-bearing stratum consisting of clay-slate, only 5·4 per cent. of the population are affected, and with granite only 2 per cent. Here the chief mineral impurities are lime and magnesium limestone. We have seen the inmates of one girls' school in a Himalayan station become affected with goître, while those of other schools not remotely situated from it, were free from this disease. The only apparent difference was the existence of magnesium limestone in the water consumed by the former, and the absence of this mineral in the latter. In these two the Author had the waters analysed by Professor MURRAY THOMPSON of the Roorkee Engineering College.*

2316.—*Are goitre and cretinism related?*

They are said to be related both pathologically and etiologically. This rule is certain that whenever from $\frac{1}{10}$ to $\frac{1}{8}$ of the population suffers from goitre there cretinism is found. It affects lower animals as dogs and cats in areas where men suffer.

Goitre sometimes may be rapidly produced. BALLY noticed that certain waters in Switzerland would cause it even in eight or ten days, and cases almost as rapid have occurred in other places.

2317.—*What diseases are brought about by the constant use of hard water?*

Goitre or bronchocele, cretinism, stone in the urinary passages, dyspepsia, and diarrhœa alternating with constipation. The continual consumption of such water is said to produce an irritable condition of the aluminating tract. It may also, it is said, produce intestinal concretions.

2318.—*What effects is a hard water said to have on bones?*

It is said to produce excessive oxidation of the bones at the base of the skull.

2319.—*Enumerate the animal parasites which have been alleged to have been found in drinking water.*

1. Tænia lata (Bothriocephalus latus), or of both this and the tænia solium and embryo of former.

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* AUTHOR'S *Hygiene of Water and Water Supplies.*

2. Distoma hepaticum (fluke)—the eggs being developed in water.
3. Ascaris lumbricoides (round worm).
4. Filaria dracunculus (guinea-worm).
5. Filaria sanguinis hominis.
6. Oxyuris vermicularis.
7. Dochmius duodenalis (Strongylus duodenalis, Sclerostoma duodenale, Anchylostomum duodenale).
8. Bilharzia hœmatobia.
9. Sanguisuga medicinalis (the speckled leech), S. officinalis (the green leech), and other species of leech.

2320.—*How does the Filaria sanguinis hominis affect the human being through water?*

The embryo is taken into mosquito's stomach with blood of persons infected with this parasite; it begins developing and is then transferred to water and so back to man.

2321.—*How may leeches prove serious parasite forms?*

By attaching themselves to the throat and larynx and producing bleeding and emaciation.

2322.—*How does the guinea-worm, or Filaria dracunculus gain entrance?*

It is said to penetrate into the subcutaneous cellular tissue of the legs of bathers. Against such a view however there is accumulating evidence. The writer feels positive that invasion through the skin is most exceptional and that the main cause is the drinking of water containing the ova of this 'worm.'

The introduction by water of *filaria* has long been a favourite opinion. It has been a matter of debate whether it is taken into stomach as drink, and thence finds its way (like *Trichnia, spiralis* to the muscles) into the subcutaneous cellular tissue, or whether it penetrates the skin during bathing or wading in streams. The latter opinion seems to be the more probable in the majority of cases.

2323.—*How does the Filaria sanguinis hominis find its way into the blood of man?*

In a peculiar manner. Dr. MANSON has found that the mosquito is an active agent in the propagation of *filaria*. The embryos are taken into the mosquito's stomach with the blood of persons infected by the hæmatozoon, the further development of which shortly begins in the stomach of the mosquito. Thence they are transferred to the water, whence it is assumed that it again finds entrance into the body of man.

2324.—*Enumerate the parasites, the ova or embryos of which are found in water and may be consumed by man.*

The embryos or eggs of the following parasites have been found in water, and may be taken into the stomach of man, when such water is used for drinking. They are:—Tænia solium, Bothriocephalus latus, Ascaris lumbricoides (round worms) Oxyuris vermicularis (thread worms), Filaria sanguinis hominis, the embryos of which are sucked from the blood by mosquitos, and then transferred to water, Bilharzia hæmatobia (?) and Distoma hepaticum (liver fluke of sheep).

2325.—*Does the Ascaris lumbricoides (round worm) gain access to the alimentary canal through water?*

It appears that they may sometimes enter the body through drinking water. At Moulmein, in Burmah, during the wet season, and especially at the commencement, both Natives and Europeans, both sexes and all ages, were forty years ago, so affected by lumbrici that it was almost an epidemic. The only circumstance common to all classes was that the drinking water, drawn chiefly from shallow wells, was greatly contaminated by the substances washed in by the floods of the excessive monsoon which prevails there. Dr. PATERSON has also noticed similar facts in England. [The oxyuris vermicularis is also sometimes taken in through water].

2326.—*How does the Ascarides lumbricoides gain access to water?*

LEUCKART has no doubt of the passage of the *ascarides'* eggs into drinking water; and, indeed, they have been actually seen in the water by MOSLER. But it seems yet doubtful (as all experiments have failed in producing from the drinking water the worms in animals) whether the eggs alone will suffice, and it seems possible that they must pass through some other host before developing in the human intestine. This is also the opinion of COBBOLD. MOSLER attributed in his case much influence to the large amount of vegetable food taken by the persons affected.

2327.—*Which of the tape-worms may reach the body through drinking water?*

Both embryo and eggs (but principally, or perhaps entirely, the former) exist in the river water. The ciliated embryo moves for several days very actively in water; it may after a time lose its ciliary covering, and then, not being able to move further, perishes or it may find its way into the body of some animal, and there develop into the *Bothriocephalus latus.*

2328.—*The embryos of the Bilharzia hæmatobia are said to live in water, what facts are on record for and against this view?*

From the observations of GRIESINGER, JOHN HARLEY, and COBBOLD, there seems no doubt that the embryos of this entozoon live in water, and the animal may be thus introduced probably by the medium of some other animal. Dr. BATHO doubts, however, this introduction by water, since the entozoon occurred in persons using rain water and pure mountain stream water.

2329.—*How does the Distoma develop?*

The eggs of the Distoma hepaticum (Fasciola hepatica) are developed in water, and the embryos swim about and live, so that introduction in this way for sheep is probable, and for men is possible.

2330.—*Are any of the specific diseases due to drinking infected water?*

A few are certainly due to this cause. That some of the specific diseases are disseminated by drinking water is a fact which has only attracted its due share of attention of late years. It is certainly one of the most important steps in etiology which has been made in this century, and the chief merit of its discovery is due to the late Dr. SNOW.

2331.—*What are the dangers that are associated with the presence of leeches, especially of small leeches, in water?*

The swallowing of small leeches, which may fix on the pharynx, and in the posterior nares is a serious matter. CLEGHORN noticed that coughs, nausea, and spitting of blood were thus caused. In a march of the French near Oran, in Algiers, more than 400 men were at one time in hospital from this cause. In some cases the repeated bleedings from the larynx have simulated hæmoptysis and phthisis, and have produced anæmia. A leech, once fixed, seldom falls off spontaneously. In India no accidents of this kind are on record, yet we must assume that they do occasionally occur.

CHAPTER XXVIII.

SELF-PURIFICATION OF RUNNING WATER.

2332.—*What conclusion did the Rivers Pollution Commissioners come to in regard to the self-purifying power of water?*

The Rivers Pollution Commission state, on the experiments made by them with a view to the solution of this question, that "it will be safe to infer, that there is no river in the United Kingdom long enough to effect the destruction of sewage by oxidation."

2333.—*Has running water such as that of streams the power of self-purification?*

Many authorities hold that running water has an intrinsic power of purification, that the oxygen of the air dissolved in the water is sufficient to oxidise and render harmless all the organic matters contained. Were the impurities limited, doubtless this would hold good, but on the banks of all large rivers, towns are situated one below the other, so that there is scarcely time for one source of contamination to be rendered innocuous, before others are added. Upon this point an interesting experiment was carried out (if we remember rightly by Dr. P. FRANKLAND) to show the fallacy of such a view. Distilled water, to which a varying quantity of sewage was added, was caused to circulate automatically in a specially constructed small circular metal drain. After it had traversed the drain a number of times representing a distance greater than that of any river in England, he found the water to be still impure.

The same erroneous notion with regard to the self-purifying power of the water of rivers prevails with regard to all large bodies of water, such as those of tanks, lakes, and large reservoirs. We would here state that no ordinary source of water-supply has such self-purifying power inherent in it.

When once a river or stream is contaminated by human excrement, it is almost impossible to state when its water becomes once more pure and fit to drink.

Although river water is seldom even approximately pure, it may usually be safely imbibed when the experience of those who have used it for a long time has proved its general wholesomeness. But absolute reliance should not be placed on this good reputation, for under special circumstances river water may become dangerously contaminated. In some instances, and at particular seasons, this is specially the case with large rivers. The smaller the stream, the more jealously should it be watched, and the more carefully should it be protected from contamination.

Drying up rivers and streams occasionally become the means of the propagation of disease from their having been infected at a higher level.

The decomposing vegetable matter washed into rivers by the rains is a frequent source of "malarial" diseases.

2334.—*What is* FRANKLAND'S *opinion with regard to the self-purification of river water in England?*

That there is no river in the United Kingdom long enough to secure the complete oxidation of the soluble animal matter present in polluted water if that pollution be from sewage matter.

2335.—*How is sewage purified in rivers?*

(1) The oxygen dissolved in the water oxidises the organic matter, the free colouring matter of aquatic plants gives out oxygen in the nascent state which helps to do the same, the solid and suspended organic matter is consumed by fishes and other aquatic animals, the organic matter readily subsides and lastly the large volume of water compared with the small volume of sewage helps to oxidise the organic matter.

2336.—*Should sewage be allowed to enter rivers?*

No, not in its crude state or before it has been subjected to some form of purification, such as downward intermittent filtration, irrigation, or treated by some chemical process which yields an effluent which has a certain standard of purity.

It has been shown experimentally that there is no river in England long enough to complete the oxidation of sewage matter before it reaches the sea.

2337.—*What are the natural forces in operation in rivers to help towards the purification of the water if contaminated by sewage?*

(*a*). Dilution.
(*b*). Subsidence of solid contents.
(*c*). The action of oxygen dissolved in the water.
(*d*). Fishes.
(*e*). Plants.

2338.—*What are the chief causes of the pollution of rivers?*

By the sewage and dirty waters from towns and of trade refuse mixing with the river waters.

2339.—*How does the refuse liquids from manufactories affect rivers? Give an instance.*

Waste liquids from different manufacturing operations meet and cause the formation of new, and in many cases, insoluble compounds. Suppose, for instance, that we have a wire-working establishment or any other iron-works, and that for any purpose, the iron is cleaned by sulphuric acid, and, as is often the case, the copper, or sulphate of iron, is allowed wholly or in part to go to waste. Suppose also there is a tannery below, the spent liquids from which run into the same stream, the result may be that the stream is converted into ink by the chemical action which takes place between the two waste liquids; the ink may be very dilute, to be sure, but the water might be too black to drink or to use for any domestic purpose.

In such a case, no doubt, the chief cause of the clearing of the water is the deposition of the coloured particles which make up the ink. Every one knows that some varieties of ink become blacker on exposure to air. The ink formed by mixing copper and tannery waste would change by the action of the oxygen of the air, but there would be no considerable destruction of organic matter; the improvement in appearance would be due to subsidence.

2340.—*To what extent does Subsidence tend to depurate running water?*

Much waste material thrown into rivers is made up wholly or in part of substances insoluble in water. A portion, and a very considerable portion, even in a running stream, is deposited upon the bottom or stranded upon the banks. This deposition can often be very plainly observed in the immediate neighbourhood of the points of discharge. Other chemical changes, besides that of oxidation alluded to above, take place, especially where the refuse is that from manufactories.

2341.—*What other processes besides subsidence help in the purification of running water?*

Although it is not practicable, in the case of a running stream, to trace the progress of the destruction of the organic material by oxidation, yet there is no doubt that an appreciable amount is so destroyed. Moreover, a considerable amount of the organic matter is consumed by fishes and by the microscopic animals which inhabit the water, or is converted into simpler compounds through the agency of plants of higher or lower order.

2342.—*How may the self-purification of running water be investigated?*

The alleged self-purification of running streams may be investigated by laboratory experiment and by observation actually on rivers. By passing water in a small stream from vessel to vessel, the Rivers Commission in England have shown that, not only is a flow of twelve miles insufficient to destroy the organic matter of sewage when mixed with water in the above proportion of one to twenty, [illegible] a flow of one hundred and sixty miles is far from sufficing [illegible] purpose. We know very well that when an organic mixture like dilute sewage is exposed to the air, decomposition—chemical change—soon sets in, and many of the substances are altered in character. It would, however, probably take an almost infinite time in a dilute solution for the oxidation to proceed far enough for all the nitrogen and carbon, which are the characteristics of the organic matter, to escape as carbonic acid, free nitrogen or ammonia, or to remain as inorganic compounds, *i.e.*, as nitrates and carbonates.

It would appear from what precedes, that there is a liability of over-rating the amount of spontaneous purification to which a running stream is subject, and it is certain that we cannot decide with confidence as to when a stream, once polluted, becomes fit to drink; moreover, as it is not possible by any practicable chemical treatment or by any process of filtration to make a polluted water wholesome, it is safer not to use as a source of domestic supply a water which is known to have been seriously polluted.

2343.—*Discuss the subject of self-purification of water.*

(1). *Vide* answer to last question.

(2). Some organic substances are readily decomposed in water. Thus, urea decomposes so rapidly into carbonate of ammonia, that it is rarely found in the most polluted waters. On the other hand, bits of muscular fibre, or of epithelium, will remain for months in water and still be readily recognized under the microscope. Even substances which decompose with rapidity when in a concentrated condition, are tolerably permanent when diluted.

(3). The Rivers Pollution Commission mixed some urine [illegible] water, in the proportion of one gallon of urine to (imperial) of water. The mixture was agitated from time to time and samples taken for analysis. The results, expressed in parts in 100,000, were as follows:—

Immediately after mixture	Feb.	17,	1874	... 0·282	... 0·243
	„	18,	„	... 0·298	... 0·251
	„	19,	„	... 0·244	... 0·255
	„	24,	„	... 0·225	... 0·253
	„	25,	„	... 0·214	... 0·269
	„	28,	„	... 0·214	0·276

2344.—*Can the experiments of the chemical laboratory show all the changes that go on in the process of purification of running water?*

In spite of various experiments [like the one just described], it cannot be denied that some chemical change does take place in a polluted stream, and the question arises, whether the readily decomposed substances are the ones which cause the injurious effects ascribed to impure waters,.or whether the products of their decomposition or the more permanent of the polluting substances may be equally injurious. Then, if the germ theory is correct, and if what we know of the permanence of other germs whose growth is traceable can serve for analogy, we should infer that these germs might well resist the action of the air or of the oxygen dissolved in the water.

2345.—*What is the standard of purity to be maintained in the effluents into river water as laid down by the Rivers Pollution Commission?*

All waters—

1. Possessing an acidity greater than that produced by the addition of 0·2 grammes of pure strong hydrochloric acid to a litre of distilled water.

2. Showing an alkalinity greater than that produced by the solution of 0·1 gramme of dry caustic soda (sodium hydroxide) in a litre of distilled water.

3. Containing, after acidification with sulphuric acid, more than 0·1 part by weight of pure chlorine to 100,000 parts.

4. Containing in solution more than 0·2 part by weight per 100,000 parts of any metal except lime, magnesia, potassium or sodium.

5. Containing more than 0·1 part by weight per 100,000 of sulphur in the condition either of sulphuretted hydrogen of a soluble sulphuret.

6. Containing in solution or suspension, in chemical combination or in any other form, more than 0·005 part by weight of metallic arsenic per 100,000 parts.

7. Containing in suspension more than 0·3 part by weight of dry mineral matter or 0·1 part by weight of dry organic matter per 100,000 parts.

8. Containing in solution more than 0·2 part by weight of

organic carbon, or 0·03 part by weight of organic nitrogen per 100,000 parts.

9. Which shall exhibit by daylight a distinct colour when a stratum of it, one inch deep, is placed in a white porcelain or earthenware vessel.

2346.—*Are some lakes and streams very pure as to organic carbon?*

Yes; there are many lakes and streams which supply water containing not much more than 0·15 part of organic carbon in 100,000 parts. As a rule, however, the quantity is much more considerable, and sometimes the water is dark and unpalatable from excess of peaty matter.

2347.—*In what manner is the sewage entering a river got rid of?*

In three ways:—1st, by subsidence, the organic matter settling to the bottom. 2nd, by the influence of water plants, which assimilate ammonia, nitrates, etc., and give out nascent oxygen. 3rd, by oxidation, doubtless a large amount of the nitrogenous matter does become oxidised in its course down a river, and in this condition is harmless. It is doubtful, however, whether the living and active germs of disease become so oxidised.

In one case, the contagion of cholera was carried 15 to 20 miles, by the river Don, from Sheffield to Doncaster. But if this is possible, it is strange that in London typhoid fever is not constantly epidemic inasmuch as it is chiefly supplied with water (filtered sewage water we may call it) which has received the sewage from 800,000 people, who live in the towns and villages along the course of the Thames above the companies' intake; there can be no doubt that typhoid fever is always more or less prevalent in these parts of the Thames valley.

Messrs. ODLING and TIDY support the view that the supply of river water to towns, even below the points where large populations have thrown in their sewage, is justifiable and safe after thorough filtration.

Messrs. FRANKLAND and VOELKER oppose this view; and Dr. FRANKLAND concludes, from numerous experiments, that no river in the United Kingdom is long enough to effect the destruction of sewage by oxidation, while Dr. A. HILL says that probably living matters do not get oxidised by flowing down a river, any more than a fish does in a similar course.

Judging by several Parliamentary decisions, the general concensus of opinion is against a river supply below a point at which any sewage has been received.

In the case of the Durham, Cheltenham and Stockton Water Bills, this point has been raised and decided in the House of Lords in every instance against the river supply.

We have no evidence as to the destruction of the poisons of diseases in running waters, but we have reason to believe that, even if they are not destroyed, they at any rate do not increase or multiply to any extent in polluted waters undergoing self-purification. If it were not so, London, which is so largely supplied with a filtered, but nevertheless polluted water from the Thames, would not exhibit so low a death-rate; for we can hardly suppose that filtration through sand or gravel can always effectually remove or destroy the countless disease germs which would be otherwise present in the water.

2348.—*What are the objections to the use of river water?*

(1) Pollution from sewage, refuse from manufactories and other contaminating agencies; (2) turbidity due chiefly to clay, at certain seasons, especially during freshets; (3) high temperature in summer in certain countries (not however in England); and (4) its being coloured if peaty.

[N.B.—The objection to the same river being a carrier of waste and a source of supply is obvious.]

2349.—*Name some trades in which the amount of organic matter reaching a river in the refuse liquid is beyond the legal limit.*

In paper-making	refuse contains	76·80	parts	organic matter	per 100,000.
,, woollen-making	,, ,,	14.30	,,	,,	,,
,, blanket-making	,, ,,	19·50	,,	,,	,,
,, flannel-making	,, ,,	91·18	,,	,,	,,

2350.—*What is the great difficulty in purifyng the refuse fluids in these trades?*

The highly deleterious nature of the polluting agents contained in the fluids.

2351.—*How may velocity of the flow of a stream be expressed?*

The velocity of flow of liquids is given by the *ordinary formula of gravity.*—

$$V = 2gh, \text{ or } V = 8\sqrt{h};$$

in which V is the velocity in feet per second; g is the velocity acquired by a body in falling freely from a state of rest, at the end of one second, being 32·2 feet per second; and h is the height in feet through which the body falls. That is to say, the velocity acquired in falling through a given height, is equal to 8 times the square root of the height in feet through which it falls; the product being the velocity expressed in feet per second.

2352.—*What standard of effluent for streams did the R. P. C. lay down?*

They stated that any liquid having the following elements in 10,000 gallons is unfit to enter a stream—

1. Containing in *suspension* more than 3 parts by weight of

dry mineral matter, or 1 part by weight of dry organic matter per 100,000 parts.

2. Containing in *solution* more than two parts by weight of *organic carbon*, or 0·3 part by weight of *organic nitrogen* per 100,000 parts.

3. Which shall exhibit by daylight a distinct colour when a stratum of it 1 inch deep is placed in a white porcelain or earthenware vessel.

4. Containing in *solution* more than 2 parts by weight of any metal, except calcium, magnesium, potassium and sodium per 100,000 parts.

5. Containing, whether in *solution* or *suspension*, in chemical combination or otherwise, more than 0·05 part of metallic arsenic per 100,000 parts.

6. Containing, after acidification with sulphuric acid, more than 1 part by weight of pure chlorine in 100,000 parts.

7. Containing more than 1 part by weight of sulphur in the condition either of sulphuretted hydrogen or of a soluble sulphuret in 100,000 parts.

8. Possessing an acidity greater than that which is produced by adding 2 parts by weight of real muriatic aicd to 1,000 parts of distilled water.

9. Possessing an alkalinity greater than that produced by adding 1 part by weight of dry caustic soda to 1,000 parts by weight of distilled water.

2353.—*Why does the running water of a river usually contain much less mineral matter than spring water?*

The surface water of a river rapidly gives off its carbonic acid gas, whereby certain mineral constituents, especially those of lime which that gas held in solution, are precipitated.

Spring water contains much carbonic acid and but little oxygen, the former gas giving to such water its fresh, brisk taste. Vegetable organisation flourishes in it, but animal bodies which require abundance of oxygen, are but sparingly represented in spring water.

Certain spring waters contain finely divided particles of *silica* and *mica* scales; especially is this so in certain springs in the Himalayas, and it is to these constituents that "hill diarrhœa" has been attributed by some authorities.

BIBLIOGRAPHY.

E. A. Parkes' *Practical Hygiene, 7th Ed.*
Stevenson and Murphy's *Treatise on Hygiene and Public Health, Vols. I and II.*
Steel's *Hygienic Physiology.*
Wilson's *Handbook of Hygiene and Sanitary Science, 6th Ed.*
L. Parkes' *Hygiene and Public Health, 3rd Ed.*
Wanklyn's *Water Analysis, 6th Ed.*
Hehir's *Hygiene of Water and Water-Supply.*
Frankland's *Analysis of Water.*
Willoughby's *Principles of Hygiene.*
Newsholmes's *Hygiene.*
F. Collyer's *Water-Supply.*
Wynter Blyth's *Dictionary of Hygiene and Public Health.*
Beardmore's *Manual of Hydrology.*
Dr. Pavy's *Treatise on Food and Dietetics.*
Crookshank's *Manual of Bacteriology.*
Halliburton's *Text-Book of Chemical Physiology and Pathology.*
Jackson's *Hydraulic Manual.*
T. R. Lewis' *Physiological and Pathological Researches.*
Pepper's *System of Practical Medicine, Vols. I and IV.*
Kingzett's *Animal Chemistry.*
Burney Yeo's *Food in Health and Disease.*
Husband's *Sanitary Law.*
Edward Smith's *Foods.*
Hehir's *Rudiments of Sanitation.*
Do. *Rôle of Water in Public Health.*
Fayrer's *Climate and Fevers of India.*
Hamilton's *Enteric Fever in India.*
Transactions *of the Sanitary Institute—Several volumes.*
Landois and Stirling's *Text-Book of Human Physiology,*
Wynter Blyth's *Poisons: Their Effects and Detection.*
Leuckart's *Parasites of Man.*
Spon's *Dictionary of Engineering, Vols. II and VIII.*
Quain's *Dictionary of Medicine.*
Baldwin Latham's *Sanitary Engineering—Sewerage.*
Sir John Simon's *Public Health Reports, Vols. I and II.*
Boulnois' *The Municipal and Sanitary Engineers' Handbook.*
Osler's *Principles and Practice of Medicine.*
Sterndale's *Municipal Work in India.*
George Reid's *Practical Sanitation.*
Aitkin's *Animal Alkaloids.*

FANNING'S *Treatise on Hydraulic and Water-Supply Engineering.*
BAILEY-DENTON'S *Sanitary Engineering.*
DEAKON'S *Brochure on Waste-Water Metres.*
Proceedings of the Institute of Civil Engineers—Several volumes.
HUGHES' *Water-Works and Water-Supplies.*
GANOT'S *Physics.*
DASCHANEL'S *Natural Philosophy.*
ATTFIELD'S *Pharmaceutical Chemistry.*
Cambridge University Examination Papers for the Cert. San. Sc.
Royal College of Physicians of London, do. do.
and the Examination papers in Hygiene of many other Universities including Edin., Cal., Madras and Bombay.

LEASH'S *Examination Questions.*
HUSBAND'S *do.*
GALTON'S *Healthy Dwellings.*
CORFIELD'S *Healthy Homes.*
BAILEY DENTON'S *House Sanitation.*
GORDON'S *Army Hygiene.*
KING'S *Manual of Hygiene.*
MCNALLY'S *Handbook of Hygiene.*
HELLYER'S *Lectures on Sanitary Plumbing.*
DUNCAN'S *Prevention of Disease.*
G. WILSON'S *Healthy Life and Healthy Dwellings.*
Do. *Guide to Personal and Domestic Hygiene.*
A. WILSON'S *Manual of Health Science.*
HIME'S *Guide to Public Health.*
SCOTT'S *Meteorology.*
MACDONALD'S *Microscopical Examination of Drinking Water and of Air.*
Health Exhibition Manual—Alcoholic Beverages.

and many other works of lesser importance.

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